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~~John Hewston Jr~~

THE USE

*J. C. Branner*

OF THE

# BLOW PIPE

IN

CHEMISTRY AND MINERALOGY.

BY

J. J. BERZELIUS.

TRANSLATED

FROM THE FOURTH ENLARGED AND CORRECTED EDITION,

BY J. D. WHITNEY.

BOSTON:

WILLIAM D. TICKNOR AND CO.

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~~John Hewston Jr~~



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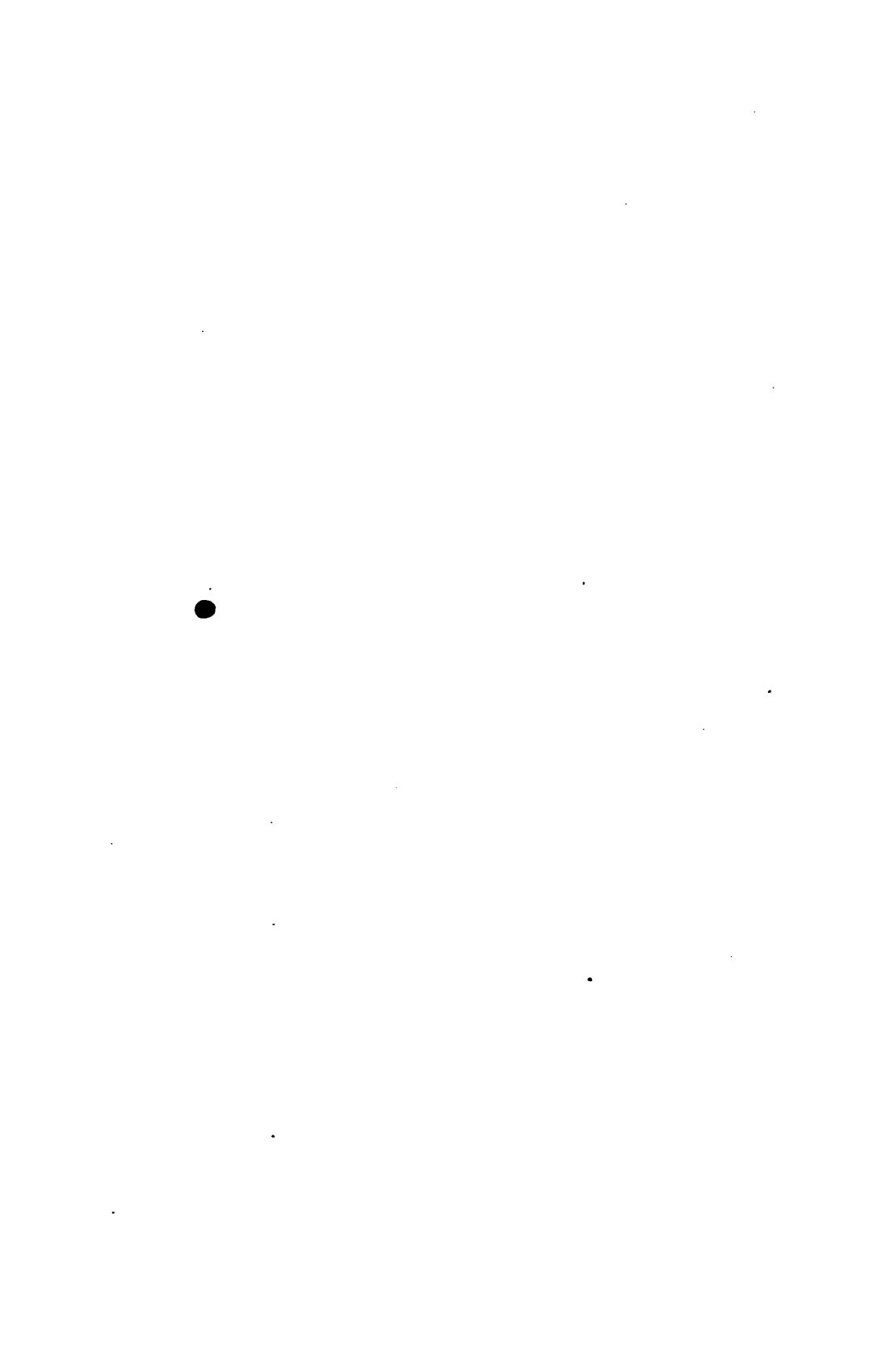
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## TRANSLATOR'S PREFACE.

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THE constantly increasing interest which is felt in the sciences of chemistry and mineralogy in this country, as well as the rapid development of our mineral resources, seems to render it expedient that a treatise on the use of that indispensable instrument, the blowpipe, should be rendered accessible to the chemists, mineralogists and miners of this country. The edition of the standard work on the blowpipe, so recently published by Berzelius, seems to contain all that could be wished for on this subject, and the translator presumes, that, if the translation shall prove to have been properly executed, he will have rendered an acceptable service to science.



## INTRODUCTION.

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THE work which I now offer to the public treats of a subject which is of great importance to the practical chemist, the miner, and the mineralogist. It constitutes a system of chemical experiments performed in the dry way, as it was formerly called, but on so small a scale as to be almost microscopic, although the results are instantly attained and decisive. In all analytical investigations of inorganic substances, the use of the blowpipe is indispensable, since by its aid all the tests necessary to determine the nature of the substance operated on may be performed with so small a quantity of the material as to be hardly perceptible to the balance, while the presence of elements, which were neither expected or sought for, is often detected. The facility with which the constituents of minerals may be determined by the aid of the blowpipe, renders the use of this instrument indispensable to the miner, who often finds his operations disturbed by the occurrence of foreign substances in his ores, whose nature he rarely has sufficient skill or time to investigate thoroughly, but which he can readily detect by the use of the blowpipe, since

the necessary degree of skill for such operations is so easily acquired. The mineralogist cannot dispense with the blowpipe; it is his only resource for deciding whether the conclusions which he has drawn from external characters, such as form, color, hardness, &c., are correct. For this reason, I have described the behavior of the greater portion of the known minerals before the blowpipe, selecting, as far as possible, for this purpose, pure and well characterized specimens. I have also given the locality of the mineral described, in every case in which I supposed that a difference in localities might give rise to discrepancies in the results, in order that such variations might not be confounded with errors of observation, which it is almost impossible to entirely avoid in so long a course of experiments, all of which it was impracticable to repeat a sufficient number of times to ensure perfect accuracy. I have also, in case of rare substances, mentioned the name of the person to whose kindness I am indebted for the specimen, partly as a surety that the mineral was rightly named, and partly as a testimony of my gratitude for the liberality with which I have been furnished with the rarest specimens for my researches. I take this opportunity of expressing my thanks to Messrs. Haüy, Bournon, Gillet de Laumont, Brongniart, Brochant, Cordier, Lucas, Weiss, Henry and Gustavus Rose, Blöde and Breithaupt.

When a mineral is met with, which is not sufficiently well characterized by its external properties, there

is, generally, only a very small number of substances with which it is liable to be confounded. It will rarely fail to be true, that the nature of the newly discovered substance can be accurately ascertained by comparing it, by means of the blowpipe, with those which it most resembles. This is exceedingly easy with metalliferous minerals; but the results obtained with the earthy minerals, on the other hand, are often less decisive, since the success of operations performed with the blowpipe depends more on the difference in the nature of the ingredients of the mineral, than on the different proportions in which the same substances may be combined with each other. But even in those cases where the same substances, by their combination in different proportions, form different minerals, there are generally remarkable discrepancies either in regard to fusibility or behavior with some one of the fluxes, so that even here the use of the blowpipe affords decisive results. It is rarely possible to determine the nature of a mineral by the use of the blowpipe alone, without any regard to external characters, exactly as attempts to decide the same question by external characters alone, without any regard to appearances dependent on chemical composition, often mislead.

Even the mineralogists of the present day, who believe that an examination of the physical characters of a mineral is sufficient to determine its nature, would in many cases be able to obtain accurate results by the aid of the blowpipe, if their, in general, deficient know-

ledge of chemistry did not prevent them from using it with advantage, whereas they now often find themselves deceived by the application of their one-sided and short-sighted principles.

An attempt has been made to form a systematic arrangement of minerals, by classifying them into genera and species, according to their behavior before the blowpipe, on principles analogous to those followed in the natural sciences generally. Aikin's mineralogy is an ingenious attempt of this kind, and I must remark, as a proof of the sagacity of the author of that work, that he has not attempted to confound that system by which the name of a substance may most easily be found out, with a truly systematic, scientific arrangement.

I hardly believe that any one will succeed in arranging minerals according to their behavior before the blowpipe, so that one who was acquainted with the use of this instrument, but who knew nothing of mineralogy, would be able to determine the names of minerals given him for examination.

Finally, I have added a short description of the method of determining the nature of the stony concretions which form in the urinary passages. I have often been applied to by physicians for information on this subject; for this reason, I was forced to have recourse to the shortest methods, and I feel myself constrained to publish the results of my experience, since by their

aid the physician may decide for himself, without the aid of a practical chemist.

Within a few years the attempt has been made to extend the use of the blowpipe still farther, and to apply it to quantitative determination, for metallurgic purposes. The researches of Harkort and Plattner, and especially of the latter, are deserving of high commendation. I have not occupied myself with this kind of quantitative analysis, and for this reason I think it better to refer to Harkort's "*Probirkunst mit dem Löthrohre*," (Freiberg, 1827,) and Plattner's work under the same title, (Leipzig, 1835,) than to attempt in the following work to describe an application of the blowpipe, which I have not myself investigated.

In the fourth edition of this work, I have added the behavior of such substances and minerals as I have been able to procure specimens of. For the correction of errors of the press and of calculation in the formulæ, which had crept into the third edition of this work, I have made use of Dr. Rammelsberg's admirable work on chemical mineralogy. I have also made an attempt to furnish beginners in mineralogy, who wish to operate with the blowpipe, with a means of comparing the mineral under examination with those already known to them. For this purpose, I have arranged the oxidized minerals in groups, according to certain decisive points of their behavior before the blowpipe.

STOCKHOLM, JULY, 1843.

J. J. BERZELIUS.





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## PART I.

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### I. HISTORY OF THE BLOWPIPE.

IN soldering small articles of metal, the workman makes use of an instrument called the blowpipe. By it, the flame of an oil-lamp is directed upon the piece of metal, which is supported upon charcoal, so that the fusible alloy which forms the solder can be heated till it melts. This instrument had long been used in the arts before its application to chemical examinations in the dry way was thought of. ANTONY VON SWAB\* was the first person, according to BERGMAN's statement, who, in 1738, attempted to use it for testing ores and minerals.

VON SWAB published nothing upon this subject, and it is not known to what extent he carried his researches.

AXEL FREDERICK VON CRONSTEDT, a Swedish Master of Mines, the founder of the system of Chemical Mineralogy, and a man who by his attainments in this branch of science was so far in advance of his cotemporaries, that he was never rightly understood by them, made use of the blowpipe to distinguish minerals from each other. For this purpose he employed fusible reagents, and, by observing the changes produced by them, he was enabled to judge correctly of the composition of the mineral. On these results CRONSTEDT based his system of chemical Mineralogy. It was therefore important to him to discover some method by which he could detect differences of composition, and which should recommend itself to the use of scientific men by its simplicity.

At the time when CRONSTEDT lived, the improvements of science were not spread with such rapidity as at present, when scientific men look with eagerness for every new addition to their particular branches. Then every one worked by himself, without any knowledge of what others

\* A Swedish Counsellor of Mines, a man of remarkable knowledge for his time, and one to whom Swedish metallurgy is much indebted.



were doing in the same department, profiting only by the labors of past generations, from which all drew, as from a common treasure-chamber. Thus, before any one even suspected the application of the blowpipe to mineralogical purposes, CRONSTEDT had arrived at a high degree of perfection in its use; a result certainly attained only by severe and untiring labor.

At that time, too, no such general interest was felt in the less important discoveries in science, as that which at the present day leads to the publication of so much that is more or less mature. CRONSTEDT, who at first did not dare to allow himself to be known as the inventor of a system which has immortalized his name, was still less likely to publish a connected description of his method of using the blowpipe. He imparted his results only so far as they served him for distinguishing the minerals described in his System.\*

VON ENGeström, who published in England, in 1765, a translation of CRONSTEDT's System, added a chapter on the blowpipe, which contained, particularly, a description of CRONSTEDT's method of using this instrument, and the principal results of its application to the various mineral substances known at that time. This treatise† was published in 1770, and was translated into Swedish by RETZIUS, in 1773. The work excited a general interest in this admirable instrument, and was immediately published in most of the European languages. For a long time, however, no advance was made beyond the results attained by VON ENGeström, and the use of the blowpipe by chemists and mineralogists went no farther than the mere determination of the fusibility of substances, or occasionally testing their solubility in the borax glass. The reason of this can be easily seen. To use the blowpipe with facility and without fatigue, or injury to the health, a certain tact is required, which can only be acquired by a course of patient practice, which is not readily submitted to by one who is not certain beforehand that his labor will be substantially rewarded. Moreover, after acquiring this facility, in order to draw a correct result from the observations made with this instrument, a large stock of observations and much experience in comparing them is required. Before attaining the required degree of experience, the use of the blowpipe gives only uncertain results, of whose real value nothing can be known.

Farther, the requisite degree of perfection cannot be ac-

\* The first edition of his work was published in 1758.

† An Essay towards a system of Mineralogy, by Cronstedt, translated from the Swedish by Von Engeström; revised and corrected by Mendes da Costa. London, 1770.

quired by mere reading. On commencing, instruction from one already experienced is required, in order that the learner may not be discouraged by little difficulties which may often be easily overcome; still, mere instruction will not always suffice, and the pupil must, himself, often repeat his attempts before he succeeds. For these reasons the use of the blowpipe was at first confined to Sweden. Those who had seen it used by CRONSTEDT and ENGSTRÖM used it as they did, and thus it became gradually known. BERGMAN extended the use of it still farther; he applied it to the whole range of inorganic chemistry, and, in his hand, it became an indispensable requisite for detecting, in analytical investigations, minute quantities of mineral substances. BERGMAN examined, with the help of the reagents described by CRONSTEDT, the greater part of the minerals known at his time, described their behavior, and improved many of the instruments necessary for these researches. He published a treatise on this subject, which was first printed in Latin, at Vienna, in 1779,\* and which was translated into Swedish, in 1781, by HJELM.†

BERGMAN's health, however, did not allow him to apply himself unremittingly to these researches. He was aided in them by JOHN GOTTLIEB GAHN, who used the blowpipe industriously in the course of his mineralogical studies, since it gave him results equally rapid and convincing. In the course of the operations which he carried on under BERGMAN's eye, he learned the behavior before the blowpipe of all mineral substances at that time known, and armed with this experience, he continued from that time to make use of the blowpipe in chemical and mineralogical investigations of all kinds. He acquired, in process of time, such skill in the use of this instrument, that he was enabled to detect, by its assistance, substances which had escaped notice in researches most carefully conducted in the humid way. For instance, when EKEBERG asked GAHN's opinion on the oxide of tantalum lately discovered by him, of which he sent him a small specimen, the latter detected tin in it by the blowpipe, although this metal formed only one per cent. of the mass. Long before it was a question whether the ashes of plants contained copper, I saw him obtain with the blowpipe distinct particles of metallic copper

\* T. Bergman, comment. de tubo ferruminatorio ejusdemque usu in explosandis corporibus, præsertim mineralibus. Vindobonæ, 1779.

† Chemiæ Professoren och Riddaren af kongl. Wasa orden Herr Torbern Bergmans afhandling om blåsörret, samt dess bruck och nytta vid kroppars undersökning, i synnerhet de mineraliske. Öfversätt från Latinska språket, med Herr Författarens tilläggningar, Stockholm, 1781.

from different sorts of paper, after burning a quarter of a sheet to ashes.

GAHN always carried his blowpipe with him, even on his shortest journeys. Every new or unknown substance was instantly tested by the blowpipe, and it was really interesting to see with what wonderful celerity and certainty he often determined the nature of a substance, which could never have been recognized by its external characters. The constant use which he made of this instrument led him to make many improvements in the use of it, and to contrive a method by which it could be always at hand, either at home or on a journey; he tried a great number of reagents, in order to discover new methods of detecting various substances, all of which he carried out with such sagacity and accuracy, that his results were worthy of implicit confidence. It never occurred to him, however, to describe his newly discovered or improved methods of experimentation, although he took all possible pains to teach them to such as wished to learn of him. Many scientific foreigners, who spent some time with him, made known his remarkable skill, although no one has ever published a correct account of his methods.\*

I had the pleasure of an intimate acquaintance with this, in so many respects, so remarkable man, during the last ten years of his life. He spared no pains to impart to me all his experience; and I consider it, for this reason, a sacred duty to allow no part of his labors or experience to be lost.

At my repeated request, he wrote down the most important part of what I have published in the second part of the Elements of Chemistry, on the blowpipe and its use in chemistry;† and this is all which he wrote upon this subject. He never drew up an account of his examinations of minerals, and, as his memory became weakened by age, he often expressed a wish that the behavior of minerals before the blowpipe might be examined and published. I therefore undertook, at his instigation, a series of experiments, the results of which he intended to control and examine, blowpipe in hand, in order that, when our conclusions differed, the cause of disagreement might be investigated, and the incorrect result struck out. This examination, which would have been so interesting to science, was put a stop to by his unexpected, and, despite his advanced age, too early death.

\* Professor Hausmann is the only person who has given a detailed account of Gahn's researches with the blowpipe, in an article in Leonhard's Taschenbuch für die Mineralogie, for 1810.

† Lärbok i Kemien, andra Delen, Stockholm, 1812, p. 273.

In the other parts of Europe only one, but he a most distinguished, naturalist has investigated in detail the use of the blowpipe. This was H. B. DE SAUSSURE, distinguished by his geological researches in the Swiss Alps. DE SAUSSURE used it principally for the same purpose as CRONSTEDT, namely, the determination of minerals; and although he introduced many improvements in the use of this instrument, he remained far behind GAHN in the results which he attained.

Since the first edition of this work was published, the use of the blowpipe has become far more general, and many more or less important additions have been made to the art, especially by LE BAILLIF, SMITHSON, TURNER, HARKORT, VON KOBELL, PLATTNER, and others.

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## II. DESCRIPTION OF THE BLOWPIPE.

The blowpipe used by workers in metal is a brass tube, tapering towards one extremity, about two inches from which it is bent at a right angle: Pl. I. Fig. 1. The aperture at this end is about the size of that made by a needle, and it is held, when the blowpipe is used, against the flame of a lamp, and blown through from the larger end. In operating with this, the workman seldom has occasion to blow for more than a minute, so that he is not incommoded by the moisture of the breath which collects in the tube; in chemical experimentation, however, in which it is necessary to continue blowing for a much longer time, so much water collects in the tube as to cause inconvenience. To provide against this, CRONSTEDT inserted, near the smaller end of the tube, a hollow ball, intended as a receptacle for the moisture. His blowpipe had the form represented in Pl. I. Fig. 2. The straight part could be unscrewed from the ball at *a*; at *b* was fixed a bone ring, which was pierced with a small hole intended to receive a needle or a piece of fine iron wire, with which the aperture of the blowpipe was to be cleaned, in case it should become stopped with soot during the operation. This blowpipe has, however, one inconvenience, namely, that if, after having been used for some time, it be held in an upright position, the water runs down into the tube, from which it must be removed, with much trouble, before the operation can be continued.

To obviate this difficulty, BERGMAN adapted to the end of

the tube a semi-circular chamber, about one inch in diameter, and one-eighth of an inch in thickness; into the upper end of this chamber the point of the blowpipe was inserted, as shown in Pl. I. Fig. 3. This instrument consists of three pieces, *a*, *b*, and *c*, which can be easily put together. This form answers the purpose excellently, and has also the advantage, that it takes up less room than the other, and can be conveniently placed in such a thin flat box as was used at that time for containing the blowpipe apparatus, so that it might be easily and conveniently transported.

GAHN changed the form of the chamber intended for collecting the water, by giving it the form of a cylinder one inch in length and one half an inch in diameter, as in Pl. I. Fig. 4, *b*. His blowpipe consists of four pieces, Fig. 4, *a*, *b*, *c*, and *d*. At the end of the small tube, *c*, a small jet, *d*, is attached, of which a number must be provided, pierced with apertures of different degrees of fineness, to be changed as occasion may require. The advantage which GAHN's blowpipe has over that of BERGMAN, is, that its cylinder takes up still less room than the flat chamber, and that the small tube can be more firmly inserted into it, and ground in more deeply as it becomes worn and loosened by use. In this way, it is not possible that the small tube should slip and fall out, as sometimes happens with the form proposed by BERGMAN. I think that the form of blowpipe adopted by GAHN may, without hesitation, be called the best and most convenient. An alteration in the arrangement of GAHN's blowpipe, which renders it particularly portable, has been proposed by MITSCHERLICH. It is this; the chamber for collecting the water is of smaller diameter and permanently fastened to the longer tube; this can be screwed apart in the centre, and the small tube with its platina jet can be slid into the part to which the chamber is attached; the other half, of which the mouth-piece is plated with silver, when the instrument is made of brass, is then slid over the whole and serves as a case. The tube is then only half as long as a common blowpipe, and is nothing more than a smooth cylinder, which may be conveniently carried in the pocket. Pl. I. Fig. 9, *B A C*, is the upper half, of which the mouth-piece *B* is plated with silver; the other end, *C*, is provided with a female screw, which fits the thread cut on the other half, *D E F*. *D* is the reservoir, and *E F* the small tube, which is provided with a platina jet, and which, when slid into its place, as here represented, is held fast by slight friction. *G H* is the whole tube slid together, so that the mouth-piece, *B*, of the part *B A C*, fits snugly against the cylindrical chamber, where it is kept by friction.

PLATTNER recommends, in the place of the usual mouth-piece, such a one as is adapted to the trumpet, intended to be pressed against the mouth, and not to be held between the lips. He gives, as a reason for this arrangement, that the muscles of the cheeks are less likely to be fatigued by this method of blowing. This fatigue, however, is only occasioned by want of practice, and soon ceases to be troublesome when the operator has become more accustomed to blowing. When the blowpipe is to be used for blowing glass, I make use of a tube, *f*, bent at a right-angle, which is inserted into the opening at *e*, and which can be inclined at any angle, as convenience may require. Pl. I. Fig. 5 shows GAHN's blowpipe put together.

VOIGT has proposed another form of blowpipe which is often used, and which is very convenient. It has at the extremity a circular chamber one inch in diameter, and one-eighth of an inch in thickness, from the centre of which a smaller tube projects, which may be turned in any direction. Fig. 6 shows this blowpipe. The inconveniences which arise from this form of construction are, that the diameter of the chamber makes it less portable, and that the movable piece gets loose after long use, allows air to escape, and no longer maintains its place. This might be easily remedied by a tube bent at a right angle, and ground into the centre of the chamber; but in any case this form of the chamber is inconvenient.

Since, in using the blowpipe, apertures of different sizes are often required, VARLEY proposed to have two points on opposite sides, so that either might be directed upon the flame, as occasion required. The convenience of this arrangement does not, however, compensate for the trouble occasioned by the loss of air through the aperture not in use. Besides, changing the platina jet is quickly performed, and is seldom necessary.

Since it is highly desirable to the Mineralogist that the blowpipe, without losing any of its essential properties, should be portable, and occupy as little space as possible, several chemists have endeavored to make it, in this respect, as perfect an instrument as possible. The forms adopted by TENNANT and WOLLASTON are especially worthy of notice.

TENNANT's blowpipe is a straight, cylindrical or slightly conical tube, Pl. I. Fig. 7, *a b*, which is closed at one end, and which has, at a distance of about half an inch from this end, an opening, into which a smaller tube, bent at an angle, is fitted by grinding, so that it can be turned in any direction. When the blowpipe is to be used, the small tube is turned at

a right angle with the larger one, or at an oblique angle if intended to be used for blowing glass ; and when it is to be laid aside, the smaller tube can be turned till parallel with the other, as shown in the figure. This instrument unites to a high degree of simplicity all the advantages which can be desired. The water which condenses from the breath flows down to the closed end, and does not enter the smaller tube. On comparing GAHN's with TENNANT's blowpipe, I have sometimes thought that the muscles of the cheeks are sooner tired by the use of the latter form, since it offers a greater resistance to the current of air than the blowpipe with a chamber, or reservoir for the air. I should compare it with the different degree of resistance which a strong or a weak spring offers to a blow. This circumstance is not unimportant, especially in mineralogical experimentation, in which the operator may be obliged to use the blowpipe for many hours in succession.

WOLLASTON's blowpipe takes up still less room than that of TENNANT. It consists of three separate pieces, Pl. I. Fig. 8, *a*, *b*, and *c*, which slide into each other in such a manner, that the whole has the diameter, but only half the length, of the common blowpipe. The smaller end of the piece *a* is fitted into the larger end of the piece *b*, which is closed at the other end, not far from which extremity a hole is pierced. The piece *c* is closed at its largest end, and ends at the other in a point provided with a small aperture. The piece *c* is pierced through and through near the larger end, so that the smaller end of *b* can be passed directly through it, not however at right angles with it, but so that the longer and smaller end of *c* makes with *b* an obtuse angle. The object of this arrangement seems to be this, that when the hole at *c* becomes enlarged by use, so that the small opening at *b* will no longer fit so as to conduct the moisture towards the closed end of the tube, where it can be best condensed, it will, however, still fit, when the aperture in *b* is turned towards the open point of *c*. This blowpipe being properly constructed, when *b* is slid into *a*, the closed end of *b* fills exactly the corresponding extremity of *a* ; and when *c* is put in its place, the aperture of *b* is closed, so that the whole is protected from dust, and can be carried in the pocket, like a common pencil-case. It has the form and size represented in Pl. I. Fig. 8. This is not a suitable blowpipe to use when the properties of substances are to be fully and carefully examined, because the joints cannot easily be made air-tight, because it has no chamber, and because the two parts form an obtuse angle, so that the flame can only be directed upon the assay when in such a position that it cannot

be properly seen. It is, however, in many circumstances, where portability is a capital object, more convenient than any other. It can be carried in the pocket without inconvenience, and, with the addition of a strip of platina foil and a bit of borax, much can be accomplished, since a lamp and charcoal can be had anywhere. I have often employed the WOLLASTON blowpipe, especially in pharmaceutical examinations, or when inspecting cabinets of minerals; and I have succeeded by its aid, in many cases, in detecting errors, and assigning to incorrectly named specimens their proper places.

Whatever may be the size of the blowpipe, its length must depend on the eye of its owner, and must be such, that the substance on which the flame is to be directed may be held at such a distance as to be best seen. For this reason, a near-sighted person will require a shorter, a far-sighted person a longer, tube. The blowpipe which best suits my eye is  $8\frac{1}{4}$  inches long, and  $7\frac{3}{4}$  inches from the aperture of the mouth-piece to the place where the point is fitted to the air-chamber.

The blowpipe must either be made of chemically pure silver, or of tinned iron with a brass point. If the whole tube be made of brass, it contracts, after being used for some time, an unpleasant smell and taste of copper. This has been attempted to be remedied by a mouth-piece of ivory or silver; but this only does away with the unpleasant taste, not the smell, and when the fingers are sweaty, they contract a coppery smell if the tube has lain for sometime unused, after having been put away without being cleaned. This is not the case if the tube be made of tinned iron, and for those who think silver too dear, it has the advantage of being still cheaper than brass. The tube and the cylindrical chamber are, in this case, made in one piece, and a bit of paper can be wrapped around the brass point to render the junction more perfect.

Although silver is a better conductor of heat than any other metal, I have never found that the tube became so heated by long continued blowing, as to be uncomfortable to hold. The small jets which are placed on the end of the blowpipe are a decided improvement. They become coated with soot, which stops the aperture or gives it an irregular shape; it must then be cleaned, and the aperture opened by a needle, which is not always at hand. This is a troublesome but unavoidable operation, since otherwise the jets dirty everything with which they come in contact. I have, on this account, had my jets made of platina, bored from a solid piece. When these become dirty, they can be heated by the blowpipe on the charcoal, which operation cleans them at once, and frees the aperture



from obstruction. If the jet were made of silver, it would not stand this treatment, since, when heated nearly to the melting point, the silver crystallizes as it cools, and becomes brittle. To produce a good flame, these jets must not be too thin at the end in which the aperture is pierced, since the smallest particle which settles in the orifice destroys the regularity of the flame, and because the aperture, by being frequently cleaned out, becomes enlarged. They are best made by boring them out for three-fourths of their length, and piercing the aperture through the remaining portion.

A glass blowpipe is certainly clean and cheap, but its brittleness, and the liability of the point to be melted, are such serious objections, that it should only be used in cases of necessity.

The attempt has often been made to construct some kind of blowpipe apparatus, which should supersede the mouth-blowpipe. DE SAUSSURE arranged a kind of blowpipe-vice, which was fastened to the table, and which was intended to hold the blowpipe, so that it could be managed by the mouth, and the hands left free. I know of no case where such an arrangement would be of advantage; besides, the form of the flame which is required in blowing depends on such slight changes in the position of the blowpipe, that it would be impossible to effect them by the movement of the mouth alone.

HAAS fastened the blowpipe by means of a screw, such as is used by ladies to pin their work to, and which is screwed to the edge of a table. Before it is placed a wax candle, which can be raised or lowered at pleasure; and not far from it the charcoal, on which the substance is to be heated, is supported by spring forceps. This apparatus is also provided with a pair of mechanical snuffers, by means of which the wick is to be trimmed into the proper shape. The operator has both hands at liberty, with which, however, he can do nothing. I do not know that this apparatus has ever been made use of.

The operation of blowing has been represented as a difficult matter, requiring strong lungs, and tending to injure the health. Partly on this account, and partly because without previous practice it is impossible to sustain an uninterrupted blast, methods have been contrived to obviate the necessity of using the mouth to produce a blast. EHRMANN, KÖHLER, MEUSNIER, ACHARD, MARCET, BROOK, and NEWMAN, have invented methods of producing a high temperature, by an artificial blast, either with atmospheric air or oxygen. These contrivances are not suited to the purpose of the blowpipe, and I shall therefore pass them by.

HASSENFRATZ employed a bellows worked by the foot, in

the manner of the glass-blowers. I saw in England a double bellows, which was placed upon the table and worked with the foot by means of a strap. The blowpipe-jet was fastened to the immovable part of the bellows.

NÄZEN proposed to fill a bladder with air, and conduct the blast from it upon the lamp by a flexible tube, terminating in a blowpipe-jet. The bladder is to be filled again by a tube connected with the mouth, and furnished with a stop-cock. Here, nothing more is accomplished by an embarrassing motion of the body, than would otherwise be easily effected by a slight exertion of the muscles of the cheeks.

For cupelling silver with the blowpipe, HARKORT proposed the use of a large bell of tinned iron, which fits into a reservoir filled with water, in which it is made to sink by being loaded with weights. To the upper end of the bell is attached a flexible tube terminating in a blowpipe-jet; the flexibility and length of the tube prevent the operator from being incommoded by the sinking of the bell.

PLATTNER partially improved this arrangement by attaching the tube to the water-reservoir by means of an inverted syphon, so that the air issues from the bell exactly as the gas is delivered from the gasometer of the gas-works. When the cylinder is emptied of its air, a valve is opened at the top, and the cylinder rises and fills itself again. The whole resembles the apparatus proposed by GAHN, for saturating water with carbonic acid gas. Something similar to this has been proposed by GREEN.

Several other similar contrivances have been proposed by different persons; but I pass them by, since all these attempts prove that the inventors had no correct idea of the use of the blowpipe, and it may with propriety be said, that they might as well have proposed to play upon a wind instrument with a pair of bellows.

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### III. THE COMBUSTIBLE.

Any kind of flame can be used with the blowpipe, provided it be not too small, whether it be that of a tallow or wax candle, or of a lamp. ENGESTRÖM and BERGMAN made use of a common tallow candle, or, preferably, of a wax candle with a good cotton wick, which, according to BERGMAN's direction, should be bent in the direction in which the flame is to be impelled. Candles have, however, this disadvantage, that the

heat radiated from the substance under examination, melts the tallow or wax from the side of the candle, and causes it to consume too rapidly. The flame of a common candle is, besides, hardly sufficient for the purpose. This induced GAHN to use, instead of one candle, three smaller ones, provided with thick wicks, which he placed in a candlestick arranged for the purpose, and burnt together. They gave an excellent flame, but he soon tired of the necessity of having a peculiar kind of candle made especially for his use with the blowpipe. He therefore replaced them by a lamp with a large wick, fed with olive oil; but as he could not use this lamp when travelling, he always took with him wax taper, combining three or four pieces of it to suit his convenience.

Lamps have certainly great advantages over candles, but they are not so easily carried about when travelling, on account of the danger of leaking. Olive oil is best used, but sperm oil can be employed, although it gives more smoke and less heat than the other.

I make use of a lamp which can be easily transported, and so effectually closed that the oil cannot escape. Since this is the form which I have found the best of the many which I have tried, for giving a suitable flame for the blowpipe, and since it is more portable than any other, I give a detailed description of it.

Pl. II. Fig. 9 is a front view of this lamp. It is made of lackered tin, slightly conical in shape, and about  $4\frac{1}{2}$  inches long. At the larger end it is 1 inch in diameter, and is furnished with a ring, by means of which it can be slid up or down upon a brass rod. This ring is seen in a side view in Pl. II. Fig. 10. At the smaller end, *b*, it measures three-fourths of an inch, and has on the upper side, near the end, a round aperture, three-fourths of an inch in diameter, to which is soldered a projecting rim of brass, one-fourth of an inch in height, on the inside of which a screw thread is cut. It can be seen in Fig. 11. Through this opening the lamp is fed with oil, and the wick placed in its holder, which is a long flattened cylinder of tin fitted into a small disk which just fills the opening. The wick-holder is seen in Fig. 12, *a* and *b*. The brass ring is a little broader than the aperture, so that the wick-holder rests loosely upon its inner projecting edge. When the lamp is not in use, this opening is closed by a brass cap, which screws into the ring, and is furnished with a leather collar, soaked in melted wax, which presses against the upper edge of the brass ring and closes the aperture, so that no oil can escape. The leather collar must be soaked in melted wax, and the

screw thread should be cut on the inside of the ring and not on the outside, since in the latter case the collar remains on the lamp, and is liable to be destroyed by the heat.

When the lamp is to be used, it is placed on a brass stand, made of a piece of thick and stiff wire. Fig. 13 shows the lamp upon its stand. The upright rod is 12 inches long, but it can be screwed apart in the centre. It is fastened, at the bottom, to two cross-pieces, each  $6\frac{1}{2}$  inches long and three-fourths of an inch broad; they are seen in Fig. 13, *d e*, in a side view, and in Fig. 14, from above. To prevent the lamp from slipping upon the rod, it is fitted to it by means of a cork, or a spiral spring can be wound round the brass rod. This latter is better than a screw or spring in the ring, as the latter is soon worn out, while the former does not permit the lamp to move upon its axis. HARKORT proposed to make another opening in the upper surface of the lamp to pour in the oil. He also cuts off the front of the lamp at an oblique angle, as shown by the dotted lines in Fig. 13, in order that the assay may be brought nearer to the flame, if necessary. The wick must, of course, be placed parallel with the lamp, and the flame must be impelled in the same direction.

If the lamp is no longer required for use, it can be taken apart, and packed so as to occupy little room, and be very portable.

A spirit lamp is often required for heating a substance in the tube or matrass, in order to detect volatile matters; for if in this case an oil lamp be used, the glass is smoked, and the requisite degree of heat cannot be obtained. The spirit lamp, however, does not by any means give as intense a heat as the blowpipe flame. I use for a spirit lamp, a kind of glass bottle, common in England, which is provided with a glass cap, which fits over the cork. I take out the cork, and fit in a wick-holder of tin or silver. The cap prevents the evaporation of the alcohol when the lamp is not in use. Fig. 15 represents this lamp of the natural size.

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#### IV. THE BLAST AND FLAME.

In using the blowpipe, the act of blowing is not directly performed by the action of the lungs, since, in this case, the effort would be injurious, and a continued blast could not be

kept up. It is effected by the muscles of the cheeks, which force the air contained in the cavity of the mouth through the blowpipe. Simple as this operation is, it is not easily performed at first, since we habitually exert all the muscles concerned in respiration at once, when we attempt to blow. It is the same kind of difficulty which we experience when we attempt to move the limbs, on the same side of the body, in different directions. It requires some practice not to allow the lungs and the muscles of the mouth to act in concert. The first thing to be attempted is, to keep the mouth filled with air during expiration and inspiration. Imagine the air to escape from a small opening between the lips, the cheeks then naturally collapse, unless a farther supply of air be admitted at the next expiration. A sufficient quantity of air must then be admitted into the cavity of the mouth to keep the cheeks constantly distended. The air, being thus always slightly compressed, escapes in a uniform current from the opening between the lips. This is what takes place in using the blowpipe; the air escapes so slowly from the fine aperture in the blowpipe-jet, that it is not necessary to fill the mouth at each expiration. This operation, which is attended with a little difficulty at first, is soon learnt by practice, and, after a short time, it becomes a matter of course, which does not interrupt the process of breathing, and on which it is not necessary to bestow a thought. The only inconvenience is, that the muscles of the cheeks become fatigued at first, which arises from want of practice, and from the fact that the beginner generally presses the mouth-piece of the blowpipe more strongly between his lips than is necessary. The act of blowing is, however, so simple, that it may be easily acquired by any one who has no natural defect in the roof of the mouth.

When the learner can keep up a steady blast, the next thing is, to be able to produce a good flame. For this purpose, a knowledge of the flame and its different parts is required. On looking attentively at the flame of a candle, it will be seen that it consists of several distinct portions. Pl. II. Fig. 16, represents the flame of a candle, in its usual form. At its base is seen a small dark-blue portion, *a c*, which becomes thinner as it gets farther from the wick, and which disappears entirely at the part where the flame begins to ascend vertically. In the midst of the flame is the dark portion, *f d*, which can be seen through the more brilliant part. This space encloses the gases rising from the wick, which are not in contact with the air, and which are therefore not yet fully burned. Around this is the proper illuminating portion of the flame, and on its outer

edges will be seen, on looking with attention, a thin envelope, *a c c*, which becomes broader near the point of the flame. This is the place in which the combustion of the burning gases is going on, and is the hottest portion of the flame. If a fine iron or platina wire be introduced into the flame, it will be seen that it is most intensely heated at the point of the flame, and if it be gradually lowered, it will be found that it is most vividly ignited at the points where it comes in contact with the surface of the flame, that is to say, where it touches this thin, feebly-illuminating envelope. If a very fine wire be used, its diameter appears much magnified, and this apparent enlargement (which is a phenomenon of the same kind as the apparent diameter attributed to the fixed stars) increases, as the wire approaches the point where the lower blue edge of the flame ends, so that the point where the flame is supplied with the largest quantity of oxygen from the air, is the place of the maximum of heat. Now, when air is forced into the flame with the blowpipe, as shown in Pl. II. Fig. 17, a long narrow blue flame, *a c*, appears directly before the jet, which is the same as *a c* in Fig. 16, although changed in form, being now concentrated into a small, cylindrical space, whereas it before formed an envelope around the whole flame. Just before the point of this blue flame is the hottest spot, as in the flame when not acted on by the blowpipe, with this difference, that in the latter case it formed a ring around the flame, while in the former it is concentrated into a focus; it is thus rendered sufficiently intense to fuse and volatilize substances which were not sensibly acted on by the flame in its usual state. On this is founded the whole theory of the intense heat produced by the blowpipe; the effect, which would otherwise be distributed over the whole surface of the flame, is concentrated into a small space, exactly as if the flame had been turned inside out. The surrounding illuminating portion of the flame prevents the heat from escaping.

Long practice is required to know where the maximum of heat is, since different substances are differently ignited, and the light which they emit is often deceptive. Care must be taken not to blow too strongly nor too gently; since, in the former case, the heat is diminished in intensity by the current of air, and in the latter, a sufficiency of air is not supplied to keep up the combustion. A very intense heat is required when the fusibility of a substance is to be investigated, or when different metallic oxides which part with their oxygen with difficulty, like the oxides of tin or iron, are to be reduced. But it is not a high temperature only which it is the design of the blowpipe

to produce ; there are other operations which require a less intense heat, and which, though diametrically opposed to each other, can be effected by the blowpipe. These are, oxidation and reduction.

*Oxidation* takes place when the assay is heated just before the extreme point of the flame, when all the combustible particles are immediately oxidized. The farther from the point of the flame, the better the operation goes on, provided the heat be sufficiently intense ; and it must be observed, that too high a temperature often impedes the oxidation, especially if the assay be supported upon charcoal. Oxidation goes on best at a low red heat. For this purpose, the blowpipe-jet must have a large aperture.

*Reduction* succeeds best with a fine jet, which should not be inserted too far into the flame, since, in this case, a highly illuminating flame is produced, the elements of which, not undergoing complete combustion, do not take oxygen from the assay, which may be considered as being heated in an inflammable gas. If in the course of the operation the assay become coated with soot, it is a proof that the flame is too smoky, which diminishes the intensity of the heat. The blue flame was formerly regarded as the proper reducing flame ; this is, however, untrue, for it is the brilliant portion of the flame which causes deoxidation, but the assay must be held in it in such a manner as to be surrounded by it on all sides, and protected from the contact of the air. I mention once more, that it is the combustible atmosphere which surrounds the assay, which effects reduction, and not the charcoal ; the reduction which takes place at the points of contact of the assay and the charcoal, would take place equally as well in the outer as in the inner flame.


The most important matter is to be able to produce at will oxidation or reduction, which is soon learnt by practice. Oxidation is so easily performed, that it is only necessary to be told how to do it ; reduction requires more practice, and a better knowledge of the management of the flame. It is an excellent plan, if one wishes to practice in making a good reducing flame, to fuse a small grain of tin upon charcoal, and raising it to a white heat, to endeavor to keep its surface brilliant. Tin has so strong an attraction for oxygen, that the moment the flame is changed in the least, the metal becomes covered with an infusible crust of the oxide of tin. One can begin with a very small grain, and gradually increase its size ; the larger the quantity of tin which he can keep melted in the metallic state, the more skilful is he in his art.

## V. THE SUPPORT.

*Charcoal.* The substance to be examined by the blowpipe must rest upon something, or be held firmly in some way. The best substance for a support is charcoal. That of mature pine, or soft wood in general, is preferable. The charcoal of the fir often snaps and throws off the assay, while that of hard and compact woods gives so large a quantity of ashes, which often contain a large proportion of iron, that it can only be used in case of necessity. For this reason the beech and oak are unfit for this purpose. I have never had an opportunity of trying box-wood charcoal, though GAHN always thought that it would be best adapted for blowpipe use; he had, however, seldom an opportunity of using any other than pine-wood coal. Of the many kinds of charcoal which I have tried in countries where the above mentioned woods are not found, I find that of the white willow, or of the willow family in general, the best. I prefer, however, the charcoal of a mature pine, which should be split into long straight pieces, and then sawn into parallelopipeds, which, when the dust is blown off, are quite clean. The surface perpendicular to the annual rings is to be chosen for the support of the assay, since, if placed on a section parallel to them, the fluxes would spread too much upon the surface. As the interval between the rings consumes faster than the ring itself, an advantage is gained, that the assay has fewer points of support.

That all charcoal which is used with the blowpipe ought to be well burnt, is a matter of course, for those pieces which snap, smoke, or burn, cannot be used at all.

GAHN conjectured that the charcoal which sometimes descends in our blast-furnaces, without being consumed, would have lost part of its combustibility, and would, on that account, be excellent for blowpipe uses. I therefore once collected specimens of this kind of charcoal from various furnaces, and found them far heavier and closer grained than common charcoal, and, of course, less combustible; but I was surprised to find that I could not obtain so high a heat on this charcoal, as on the common kind. I ascribed this, at first, to the heat radiated from the particles of coal set on fire around the assay, when the common combustible kind of charcoal was used, which I supposed might have a decided influence in raising the temperature; but I soon discovered my mistake, when I found that the charcoal became so strongly heated at a considerable






distance from the spot upon which the flame was directed, that I could no longer hold it. This kind of charcoal is a better conductor of heat in proportion as it is denser, and it is probable that this is the reason why it burns so slowly. It is, therefore, unfit for use with the blowpipe.

*Platina.* In certain cases, in which the reducing action of charcoal might impede the desired reaction, platina may be employed as a support; sometimes in the form of a small spoon, sometimes in thin foil, and sometimes as a fine wire.

a. *Platina spoons.* For a long time spoons of gold or silver were used in the treatment of minerals with soda; but these are too easily melted, or injured by a strong heat. They are now made of platina. The spoon is one-fourth of an inch in diameter, and one-twelfth of an inch deep, and is fastened to a narrow, short and pointed handle, which can be thrust into a piece of charcoal, so as to be easily managed. The thinner the metal of the spoon, the higher the temperature to which it can be raised. I have seen them in England, stamped in thin platina foil, which was doubled on each side of the handle, so as to make it sufficiently stiff, exactly as small tin spoons are often made. The platina spoon is an instrument which can be dispensed with in blowpipe operations, since it has been found that minerals can be best treated with soda on charcoal. Besides, the size of the spoon renders it difficult to attain the high temperature which is often required.

b. *Platina foil.* WOLLASTON introduced, instead of the spoon, thin platina foil, which should be cut into strips of a few inches in length, and half an inch broad. This foil can be intensely heated, since the thin metal conducts away very little heat; when it is desirable at the same time to heat and oxidize the assay, the flame can be directed upon the under side of the foil. Platina is so bad a conductor of heat, that when the assay is heated upon one end of a strip of foil, the other end may be held in the fingers without inconvenience. Care must be taken not to treat such minerals on platina foil as are reducible to the metallic state by the action of the blowpipe, because the platina, in that case, combines with the metal, fuses, and becomes perforated. With care such a strip may be made to last for a long time; should it be injured, a piece can be cut off, and when the strip becomes too short to be held in the fingers, it can be held in the forceps.

c. *Platina wire.* GAHN, who saw at once the inutility of the platina spoon, but was not acquainted with the use of the foil, contrived another method of using platina as a support, which far surpasses either of the others, and permits us to dispense with the spoon and foil in most cases.



A platina wire is bent into an eye at one end, as shown by Fig. 18, Pl. II., which eye serves as a support in the following manner. It is moistened by the mouth, and then dipped into the flux, of which a small quantity adheres to it, which, when melted to a bead, remains attached to the eye. The assay is then moistened, so that a part of it adheres to the bead, and the two are then subjected together to the action of the flame. The melted mass is then in a position in which it can be conveniently examined; since it is free from the deceptive play of colors, which is often caused on charcoal, by the adherence of the assay to the dark colored ground.

This method answers the purpose so perfectly, that it is, in most cases, far more serviceable than the charcoal, and it can be advantageously used in all cases, excepting when a metal is to be reduced by the blowpipe flame. In general, all attempts to oxidate, and all researches in which a change of color in the fluxes is to be looked for, must be performed upon the platina wire. I must here remark, that platina does not combine with phosphorus during the ignition, and that it is consequently not injured by the salt of phosphorus. I have attempted in vain to cause it to combine with phosphorus, even when the salt of phosphorus was mixed with boracic acid, and heated with it upon charcoal.

When the flux has been heated till the proper reaction has been obtained, if it is wished to prevent a re-oxidation by rapid cooling, the bead can be thrown from the wire, by a slight jerk, on to a cold body, such as a tea-cup, or a small anvil, where it cools instantly, which is often of service. Several wires must be had ready, so as not to be obliged to forcibly detach the glass from the eye in order to clean the wire; it can be dissolved off in water afterwards, at leisure.

SMITHSON uses the platina wire for holding a small splinter of a mineral which is to be heated; he attaches it to the end of the wire with fire-clay. The clay is first gently dried in the flame, so that it may not be blown away from its position.

In travelling, the platina wire is indispensable, for it is not always possible to procure the proper kind of charcoal, and not easy to transport a large quantity. It can thus be kept for those operations in which it is required to reduce a metal to its metallic state, or where a mineral containing sulphur or arsenic is to be roasted. As to the size of the wire, it is not a matter of consequence, though the finer it is, the better, provided that it does not bend when heated. If too coarse, it conducts away too much heat.

*Disthene.* DE SAUSSURE made use of the mineral called

disthene, kyanite, or sappare, before the use of platina foil was known. This mineral can be divided into small slips, which may be fastened at one end to a bit of glass tube, which answers the purpose of a handle; the assay is then attached to it by being moistened, or by a little gum water. This substance is, however, not so common that it can always be obtained, and its use is rendered quite unnecessary by the introduction of platina. The disthene is, moreover, attacked by the fluxes.

*A strip of mica* can sometimes be used as a support for the roasting of metallic ores, if the reducing influence of the charcoal is to be feared.

Fire clay can also, according to SMITHSON, be used for this purpose. The clay is to be beaten out into a thin sheet, between two pieces of paper, with a flat, smooth hammer. It can then be cut into acute-angled triangles, broad strips, &c. The best way of preparing them is this: an equal quantity of burnt and unburnt clay must be kneaded with water to a stiff paste, which is to be laid on paper, and then covered with soft paper; it must then be smoothed with a roller, for which purpose a cylindrical bottle can be used. The mass is to be cut up while moist, and dried in the air, and afterwards under a press, since otherwise it would warp and crack. The form of small cupels can be given to the pieces, by cutting out round disks, and then pressing a concavity in the upper surface by a stamp of proper size, turned out of hard wood. These clay slips withstand the action of borax, and are not attacked by the oxide of lead. They must be heated in the flame of a spirit-lamp, before being used, to drive off hygrometric moisture. They are best held in the hand; but small pieces, and the cupels are to be laid upon charcoal.

*Glass tubes.* In case the assay is to be roasted in such a manner as to detect the substances which may be volatilized in the operation, I make use of a glass tube at least three inches long and one-twelfth of an inch in diameter, open at both ends. The assay is placed in this, near one end, and the tube is to be held with this end slightly inclined downwards. According as more or less heat is required, the spot where the assay lies is to be heated with a spirit-lamp or by the blowpipe flame; and the tube can be inclined more or less, as a stronger or lighter draught of air is required. Substances which are volatilized by this operation, but not gaseous, sublime into the upper part of the tube, and can then be recognized. This small piece of apparatus is seen in Fig. 19, *a*, Pl. II. Although straight tubes require no previous preparation, and are therefore easily pro-

cured, there is one difficulty attendant on their use, which is, that the assay is apt to fall out, if the tube be inclined before it is so softened by the heat, that the substance under examination can fasten itself to it. It is, therefore, better to bend the tubes near the lower opening, at an oblique angle, into the form shown in Fig. 19, *c b d*. The assay is then to be laid in the angle at *b*, and the tube can then be inclined at an angle sufficient to allow the gaseous vapors to rise, without danger of its falling out. When a very slight draught of air is required, the aperture at *c* can be made smaller by melting it together. This is especially useful in detecting selenium when roasting sulphurets, since the slight access of air does not allow the selenium to become oxidized. Still another kind of tube will be mentioned under the head of arsenious acid.

*Glass matrasses.* When the assay is to be examined for water or other volatile matters, or when it is liable to decrepitate, it must be heated in a glass tube closed at one end, and slightly enlarged at the other, so as to have the form of a small matrass, *A*, Fig. 20, Pl. II., since the volatile matters are more easily driven off when the air is allowed to circulate in the apparatus.

When, on the other hand, combustible substances are to be sublimed from the assay, as sulphur, arsenic, &c., the tube must not be enlarged at the closed end, to avoid combustion, which might be caused by the circulation of air.

VON ENGSTRÖM proposed to heat decrepitating substances in a cavity in the charcoal, by covering it with another piece of coal, leaving a small aperture into which the flame of the blowpipe could be directed. WOLLASTON placed the decrepitating substance in a fold of platina foil. BERGMAN used glass tubes closed at one end, and also a platina spoon, closed by a lid provided with a hinge. GAHN preferred the small glass matrass to any other contrivance, but he used it only for decrepitating substances, and paid little attention to the reaction obtained by sublimation.

The glass tubes and matrasses which are used for the examination of metallic substances, are often destroyed in the course of the operation. For this reason, it is necessary to be provided beforehand with a supply. It is troublesome to carry them in travelling, and difficult to replace them when broken. I am in the habit of cutting glass tubing into pieces of five or six inches in length, which I keep in a wooden or tin case. The place where the glass tube has once been exposed to the flame cannot be a second time heated without cracking, as the glass generally loses its shape. For this reason a piece must be cut

off with a file, and the tube then cleaned with a bit of paper wound round a wire. Thus with one piece seven or eight operations can be performed, since each one will not require more than half an inch to be cut off. In the same manner the closed tubes can be cut off and cleaned.

The matrasses are rarely exposed to so high a temperature as to be destroyed. They can, therefore, be used for a long time, but still it is best to have a few in readiness in case of accident. Those tubes which are merely closed at one end, without being enlarged, are best made as wanted, by sealing up one end with the blowpipe, by means of the spirit-lamp. Thus the same piece of tube can be used, open or closed, as occasion requires. When the piece is too short to be used as an open tube, it will still answer the purpose when a closed tube is required.

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## VI. INSTRUMENTS WHICH ARE REQUIRED WITH THE FOREGOING.

1. *Forceps.* Forceps, or tongs of various kinds are used for different purposes.

a. *Forceps to hold the assay during the operation of blowing.* It often happens that small fragments are blown away by the current of air produced by the blast upon the charcoal. They must, in such cases, be held by forceps, of which the whole, or the points only, are of platina.

They are best made of steel, of the form shown in two views, Pl. III. Fig. 21, *a b*, are two small strips of steel, of the form shown in the figure, to the ends of which platina points are attached, by means of two small rivets. These steel slips are fastened, in the middle, to a small plate of the same metal, which lies between *e e*, so that a double pair of forceps is formed, which, at one end, have broad steel points, separated from each other, and at the other, narrow and long platina points, which are closed upon each other by the elasticity of the steel part of the instrument. In order to open them, each piece has a small projection, *d d*, passing through one limb and attached to the other, so that when they are pressed between the thumb and finger the platina points separate, and, if the pressure be relaxed, the elasticity of the steel holds the assay firmly.

The platina points must be sufficiently stiff at *b* not to give way to the elasticity of the steel, but they must diminish in size towards *c*, in order not to conduct away too much heat. The steel points must be tempered at *a*, in order not to be scratched or blunted, when used to break off small fragments of the specimen for examination. This kind of forceps has been introduced among us from France, and it answers the purpose admirably.

A less convenient form is used in England. It is represented by Fig. 22, Pl. III., in profile. The legs, *ab*, are of brass, and are attached together at *b*, like the former kind. At *b* two platina points, *bc*, are riveted, as before. The forceps are kept open by the elasticity of the metal, and are shut by a double button, *d*, which slides up and down in a slit cut in the legs. When the button is slid towards *c*, the legs shut closer together; *ee* are two bits of wood, fastened to the legs, by which the forceps are held, since brass is so good a conductor that the fingers are liable to be burnt, if the operation be continued for some time.

b. When anything is to be held more firmly, a pair of iron forceps is used, made like the foregoing, and represented by Pl. III. Fig. 23. The button, *dd*, by which the forceps are closed, is provided, on one side, with a steel spring, to hinder the forceps from opening from the sliding back of the button, when a large object is grasped.

c. To break off small fragments from the specimen without striking it, or to divide small fragments, a pair of cutting-pliers, like Fig. 24, is used; the edges ought, however, rather to be broad and strong, than sharp, since otherwise they would soon be gapped.

d. A peculiar kind of forceps for trimming the lamp-wick. For this purpose I use a pair of iron forceps with long points.

2. *Hammers.* It is necessary to be provided with two hammers, both of good and well hardened steel. One must have, at one end, a round and polished surface, to flatten out globules of reduced metals; the other end must terminate in a blunt point, which is to be used for breaking off pieces for analysis, when the blow requires to be struck on a small surface. The other hammer must be square at one end, and at the other it must terminate in a broad sharp edge to answer as a sort of chisel, in case of necessity. Such a hammer is represented by Fig. 25, *a*, Pl. III. This is used to break off fragments for analysis, and the sharper the corners and edges, the less the injury to the specimen. If they become rounded, the hammer must be ground sharp again.

3. *An anvil.* An anvil is needed to break up fragments of minerals, and also to flatten out reduced metals. VON ENGELSTRÖM and BERGMAN used polished steel disks, an inch square, and one-fourth of an inch thick. In order that the specimen may not be thrown about by the violence of the blows, a steel ring is placed in the middle of the disk, inside of which the fragments are confined. GAHN changed the form of the anvil to that of a parallelopiped about three inches long, one inch thick, and five-eighths of an inch broad, Fig. 26. This has the advantage that the anvil has several surfaces, which can all be used. It is also sufficiently strong to resist every blow, and can easily be packed with the other instruments, in the manner which I shall describe. The ring is an entirely unnecessary addition, which does not answer the purpose intended. If a substance is to be broken in pieces, it must be wrapped up in paper, laid upon the anvil, and struck heavily with the hammer. The paper prevents the fragments from being scattered about, and although it breaks in pieces, the powder can be taken out without loss. To flatten out the grains of reduced metals, the best way, in my opinion, is to cover the grain with thin paper, and then to press upon it with the finger; in this way, a projection is left where the globule lies; the paper can then be held fast by the fingers, and the metal flattened out. If the metal be brittle, the powder remains on the spot; if malleable, a scale is obtained, which fastens itself by its ragged edges to the paper, and can thus be conveniently examined.

4. *A knife.* A knife of good steel is required for many purposes; it must be so formed that the edge be blunt, and the point bluntly ground off, but sharp. This knife can be magnetized, so as to answer the purpose of a magnet. I use a pen-knife with a blade which can be shut up. With such a knife the hardness of substances is determined, by observing whether they are more or less scratched by steel. With the point of the knife, when moistened in the mouth, the fluxes are taken up, and, when necessary, they can be mixed by it in the palm of the hand; in short, the knife is one of the most indispensable instruments of the blowpipe apparatus.

5. *One or more files.* Triangular, flat, half-round, and round, are used on many occasions, which it would be idle to enumerate.

6. *A small mortar with its pestle*, of agate or chalcedony, the smaller the better. The one which I use is not quite two inches in diameter, half an inch high, and the concavity ground in it is five-sixteenths of an inch smaller each way.\* It is de-

\* Gahn, once having lost the pestle of his mortar, took a chalcedony bottom

sirable that the bottom should be slightly transparent ; it must also be free from holes or flaws, in which the pulverized substance might collect.

A small piece of pumice stone must be kept for cleaning the mortar, since, otherwise, it is difficult to remove the traces of metalliferous minerals from the surface of the mortar.

7. *A conical tube of tinned iron*, Pl. III. Fig. 28, the ends of which are filed away so as to leave a cutting edge. This cone is used to bore cavities in the charcoal ; the larger end makes a larger, the other end a smaller, hole, which is smooth at the bottom, and regular in form. The figure shows the conical tube, containing a phial, for which it serves as a case.

8. *A microscope*. Fig. 27 shows the best form of the microscope, which takes up little room, and is conveniently used. It has two lenses of different magnifying powers, which must be plano-convex, as suggested by WOLLASTON, in order to increase the field of vision. This instrument is quite indispensable in this kind of experiments, and colors should never be decided upon without its aid, since the reflection from the surface of the coal often causes, in small beads, a deceptive play of colors, which disappears under the microscope.

9. *A box for preserving the reagents*. In these researches it is highly desirable that the fluxes should be so placed that they can be conveniently taken out for use, especially when certain experiments are to be made, in which a decisive result cannot be taken for granted, but when, notwithstanding, the use of any one of the fluxes may, unexpectedly, decide the question. This circumstance induced GAHN to contrive a box in which all the reagents could be kept so as to be at hand when wanted, and in which the separate compartments could be opened and shut by the right hand, and the flux taken out, without the necessity of laying down the assay and its support, which is held in the left hand. The form which GAHN at last fixed on is represented by Pl. III. Fig. 30. It is a box  $8\frac{1}{2}$  inches long, and  $1\frac{3}{8}$  inches broad, and when shut, 1 inch in height. It is divided into nine cubical compartments, each one of which is provided with a closely fitting lid, and it has also a common lid for the whole, which can be closed by a couple of hooks. To render this lid more secure, it is provided with two cross-pieces, which fit into spaces left between the lids of the second

which had a surface fitted to the concavity of the mortar, and fastened it with shellac, to a handle of cork ; he never afterwards required any other. I was compelled to make one in the same way, and mention this, that others who may happen to be in the same difficulty, may have recourse to the same expedient.



and third compartments, counting from each end. The common lid is fastened by metal hinges, while the smaller lids turn on a common axis, which passes through all of them. These joints require to be made with considerable care, and make the box dearer than it would otherwise be. This expense may be partially obviated, by making the hinge of a strip of morocco leather fastened to the back of the box, which, bending as the cover is raised, answers as well, if not better, than a metal hinge. Each reagent which is most often required has a separate compartment, and those which are only very rarely used can be wrapped in paper, and a number of them placed together in one division of the box. In travelling, wide-mouthed phials may be used with advantage; they can be closed with corks. As many small phials, or turned wooden boxes, as are required, may be placed in a case of lackered tin, of the form and size of the wooden box above described, into which they may be made to fit. The box should be two-thirds of the height of the phials, and the cover may be put on, without a joint or hinge, like the lid of a common snuff-box. This method of preserving the fluxes was introduced by SEFSTRÖM, at the School of Mines at Fahlun, and is used by the pupils on their excursions to the mines.

10. *A plate of sheet-iron, 12 or 14 inches square, with a rim half an inch wide, turned up at the edges.* This plate is used to contain the lamp while it is in use, in order that when substances should fall from the support, they may be easily found on this plate. For this purpose, the bottom should be kept covered with clean paper.

11. *A cork, through which passes a glass tube, with a fine opening at one end, Pl. II. Fig. 20, B.* This tube is inserted into a bottle half filled with water, and answers the purpose of an edulcorator, in certain reductions, which will be described further on, where the charcoal powder is to be washed from the reduced metal. Since bottles and water can everywhere be had, it is only necessary to take the tube in a travelling case. It can be inserted into a very conical cork, in order to fit a variety of sizes of bottles.

12. In travelling, a *cylindrical bottle of tinned iron*, fastened by a screw cap, like the blowpipe-lamp, is useful. It is intended to contain a provision of oil, which, in travelling, it is often difficult to procure of good quality.

13. *A square case of tin*, for several large pieces of charcoal, which must be wrapped in paper before they are placed in it, since, if they lie loose, they are apt to be shaken to powder, which escapes and covers everything with dirt.

14. *A small oblong box of lackered tin*, which is provided on the inside with silk cushions, which fill the whole box. Between these cushions the small loose parts of the blowpipe apparatus are to be kept, such as platina jets, foil and wire, a fine needle to clean the aperture of the jet when necessary, and a small blood-stone to try whether the reduced but unmelted metallic substances have a metallic streak.

15. *A case of tin or wood*, for glass tubes.

16. *A match box*, for which I generally use a small phial of phosphorus, closed with a tin or glass stopper, which must be smeared with tallow.

17. *Several cylindrical boxes*, which are intended to contain a provision of those fluxes which are most often required, such as borax, salt of phosphorus, and soda.

18. *Several small porcelain capsules*, three-fourths of an inch in diameter, and three-eighths of an inch in depth; they are intended for preserving the fragments of minerals intended for examination, and for the substances which have been tested, and laid aside for description.

All these instruments must be kept where they can be conveniently reached, without the necessity of stopping to look for them. There are two methods of attaining this end, one when the apparatus is to be used at home, and another when it is required for use in travelling. I will describe both methods as used by GAHN, of the utility and convenience of which I have, by long experience, become convinced.

To arrange and preserve the blowpipe apparatus at home, a peculiar sort of table is used. The form is not a matter of much importance, but Pl. IV. Fig. 34, represents the table used by GAHN. In the narrow ends of the table, two drawers are inserted, which are represented in the figure as drawn out, to show their peculiar and skilfully contrived arrangement. Each drawer is supported by two side pieces, which are fastened to its bottom, and are much longer than the drawer itself. These pieces slide in grooves made in two slips of wood fastened under the drawers, and prevent the drawers from slipping out entirely and falling, when opened far enough to expose the back compartments.

These two drawers are especially destined for preserving the blowpipe apparatus. In the right hand drawer are placed the most important and most frequently used pieces of apparatus. Those which are not so often used are kept in the left hand drawer. To prevent the instruments from getting into disorder, the drawers are divided into compartments, by tin boxes, which are more easily taken out and cleaned, than

25. *A steel magnet*, for performing HAÜT's experiment of double magnetism.\*

26. *A small pair of scissors.*

27. *A small pair of pliers*, to take off and put on the crucibles, when heated by the spirit-lamp.

28. *A small touchstone, and several needles of gold alloys*, for trying the fineness of gold.

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## VII. THE REAGENTS, AND THE METHOD OF USING THEM.

CRONSTEDT used generally but three reagents; basic carbonate of soda, borate of soda, and the double salt of the phosphate of soda and ammonia, which I shall call hereafter, for the sake of brevity, by their common technical names, soda, borax, and salt of phosphorus. These reagents are all still in use, and among the great number of those which have been tried since that time, not one has been found to replace either of these. It is singular enough, that, in the very beginning of the art, the very best reagents should have been hit upon. In addition to these, which are constantly required, others, intended for certain special purposes, are not so often used, but must be at hand, as occasion may require. I will speak of each reagent by itself, of the purpose it is intended to accomplish, and the method of using it.

1. *Soda* (carbonate of soda). For this purpose the carbonate or the bicarbonate may be used; but it must be perfectly pure, and, especially, free from sulphuric acid. It is best prepared by dissolving the common refined soda of the shops, and impregnating the saturated solution with carbonic acid, by which operation the bicarbonate of soda is thrown down, in

\* This experiment is intended to detect the slightest trace of magnetic force in minerals, and is thus performed. A magnet is placed at a small distance from the suspended magnetic needle, the north pole, for instance, turned towards that of the needle; it is then gently moved toward the needle till it takes a position at right angles to its former place, caused by the repulsion of the same kind of electricity. The repulsion of the magnet and the force of terrestrial attraction now hold the needle exactly balanced between them, so that the smallest disturbing magnetic force moves it out of its place, and the attractive power of the magnet prevails. In this way an amount of magnetic force may be detected which would not be sufficient to affect the needle in its ordinary state. In performing this experiment, care must be taken not to excite electricity in the mineral by handling it, since it would exert the same attracting power as magnetism.

the form of a white crystalline precipitate; this precipitate must be washed a few times with cold water, and then dried. The salt can be kept in powder, either as obtained by this process, or after being ignited. In the former case it takes up more room, but in the latter state, when a moistened knife is introduced to take out portions of the soda, the remaining portion is rendered lumpy by the absorption of water.

The object of the use of soda is, in general, two-fold: a. to determine whether substances, when melted in it, are fusible or not; and, b. to assist in the reduction of metals. Both are operations of the highest importance, and render soda the most indispensable of the fluxes.

a. *The fusibility of substances in soda.* A great number of substances have the property of combining with soda at a high temperature, but the greater part of these combinations are infusible. Soda produces fusible combinations with acids and with a few metallic oxides, including silica. These are for the most part absorbed by the charcoal. The combination which most frequently occurs, is the glass formed by it with silica or minerals containing silica, of which I will speak farther when treating of silica and the silicates.

When soda is to be used, certain small precautions are to be observed. It is to be taken out of the box in which it is kept with the point of the knife moistened in the mouth, in order that the powder may adhere to it. It is to be placed in the hollow of the left hand, and, if necessary, moistened with a little water, and then worked into a coherent mass. If the substance to be examined is a powder, it must be kneaded up with the soda; but if it be a thin scale or fragment, it must be covered with the soda, and then gradually heated on the charcoal to the melting point. It often happens that the soda will be absorbed by the charcoal at first; this does not hinder its reaction upon the assay, for if it is soluble in the soda it will draw it out again; a constant effervescence is seen upon the surface of the assay, the edges become rounded, and it is soon converted into a melted globule of glass. If, on the other hand, the assay be not soluble in soda, but be decomposed by it, it is seen gradually to change its appearance, but without melting. However, before coming to the conclusion that such a substance is insoluble in soda, it must have been mixed with the soda in a pulverized form. If too little soda be added to the assay, a part of it remains undissolved, surrounded by a clear glass; and if too much be added, the glass, on cooling, becomes clouded. In order, in each of these cases, not to be deceived by an element of the substance examined, which

might be insoluble, and thus cause an opacity in the bead, more of the same substance must be added, to see if in that manner a transparent glass can be obtained. In general, it is always best to add the soda in small portions, to observe what effect varied proportions of the flux may produce.

It often happens, that, in this operation, the glass while cooling becomes colored, and assumes a tint varying from yellow to a deep hyacinth red, or becoming even opaque and dark yellowish brown. This happens when the soda or the assay contains sulphur or sulphuric acid, the color being produced by the hepar or liver of sulphur, which is formed by the reducing action of the charcoal. If it always occurs with the same soda, it is a proof that it contains sulphate of soda, and it is therefore unfitted for blowpipe uses; but if the soda generally gives a colorless glass, the assay contains sulphur or sulphuric acid.

CRONSTEDT and BERGMAN prescribed the use of a metallic spoon, in which the soda was to be melted with the mineral, because they believed that the absorption of the flux by charcoal might prevent its action upon the assay. GAHN never used the spoon for this purpose, because by performing the operation on the charcoal, the melted mass assumes a globular shape, of which the color and degree of transparency can be accurately observed, while, on the contrary, it spreads over the surface of the spoon.

b. *The reduction of the metallic oxides.* This operation, by means of which quantities of reducible metals are often detected which would escape the test in the moist way, unless very large quantities were operated on, I consider the most important of GAHN'S discoveries in the use of the blowpipe.

When a small quantity of native or artificial oxide of tin is placed on the charcoal, a practised blower can obtain from it, with some difficulty, a metallic globule; but if a small quantity of soda be added, the reduction is effected with ease, and, if the oxide be pure, it is entirely converted into a globule of tin. The soda then assists in the reduction in a positive manner, but in what way is not exactly known. Since the substance which is to be reduced is surrounded by soda, and its contact with the charcoal rather hindered than favored, the soda may, during the operation, undergo partial reduction, by means of which the enclosed oxide is brought to the metallic state, by the action of the radical of the soda or its suboxide. If the metallic oxide contains a foreign body, which cannot be reduced, it is often difficult to bring it to the metallic state; but if a small quantity of borax be added, which contributes by its presence to the solution of the foreign substance, the operation can be effected,

and the metal is generally much easier recognized, since the character of the substance under examination had previously been determined with tolerable certainty, and the reduction is only performed for the sake of confirming previous experiments. This kind of reduction has been described by BERGMAN.

But let us suppose the metallic oxide mixed in small quantity with other non-reducible substances, and that its presence is not known, or that it cannot be determined with certainty by other tests, in what way can it be discovered whether the assay contains a reducible metal, and how can it, in this case, be extracted? This question has been answered by GAHN in the following simple manner.


The assay is to be pulverized and mixed, in the palm of the hand, with moist soda, to a paste; it is then to be laid upon the coal, and heated in the reducing flame. Upon this, more soda is to be added, and the operation continued. As long as any portion of the assay is still remaining unabsorbed by the charcoal, more soda is added, and the blowing kept up, till all has been absorbed. The first and smaller portions of soda serve to collect the metallic matter scattered through the mass, and the final absorption of the mass into the charcoal, completes the reduction of that part which had not before been reduced. The coal is then moistened with a few drops of water, and all that part of it into which soda has been absorbed is to be broken out and finely pulverized in the small mortar. Water is then to be poured upon it, to wash away the fine coal-dust; the washing-tube answers this purpose excellently; this operation must be repeated till all the coal has been removed. If no metal was present in the assay, the mortar is left empty; but if it contained ever so small a quantity of reducible metal, small, flattened, brilliant scales of metal are found, if the metal be malleable; or a metallic powder, if it be brittle, or cannot be melted. In both these cases the metallic streak, produced by the friction of the metal in the mortar, can be seen. Should the quantity of metal contained in the assay be exceedingly small, the metallic streaks are often not to be observed. The flattening of the malleable metals has the effect that an almost invisible grain becomes flattened out into a plate with quite an appreciable diameter, while at the same time its surface receives a burnish. In this way, a quantity so small as one half per cent. can be detected in a specimen of tin of the usual size for blowpipe experiments, and of copper the smallest trace can be detected and rendered visible.

Care must be taken in these operations, to keep the tempera-

ture as high as possible, and to envelope the surface of the flux as much as possible with the reducing flame. None of the substance must be allowed to remain attached to the charcoal, or be washed away, since when the mineral collects in a grain, it is impossible to say in what part of the mass it may lie; the coaly mass must be slowly and carefully pulverized, and cautiously poured off, so that only the lightest and finest particles may be carried away with the water; the result should not be determined till all the coal has been washed away, since small scales of the metal may be concealed by the coal, and the particles of coal seen in a peculiar light have a metallic lustre, which might deceive the inexperienced. Lastly, the assay should always be examined with the glass, even if it should be large enough to be seen with the naked eye, in order to be certain that no error has been committed. It often happens that a mortar, which has been a long time in use, has small cavities which are filled with air, and form bubbles under the water, whose convex surface reflects the light like a metallic substance. It is, however, easy to recognize the true nature of the reflecting surface, in such a case, by turning the bottom of the mortar to the light; if it be a bubble it will be transparent, if a scale of metal, the spot will be opaque.

The metals which can be reduced in this way are, the precious metals, molybdena, tungsten, antimony, tellurium, bismuth, tin, lead, copper, nickel, cobalt, iron. Among these, antimony, bismuth, and tellurium are easily volatilized, if a strong heat be used for the reduction. Selenium, arsenic, cadmium, zinc, and mercury, are so easily volatilized, that they cannot be collected except in a small apparatus for sublimation. The process of reduction can be successfully performed by the beginner, if the assay contains 8 or 10 per cent. of metal. If, however, the proportion of metal be less, more care and more practice is required to keep the reduced metal in the mortar, and to detect it. To acquire practice in this operation, a substance containing copper is best chosen, and at each successive experiment the quantity of copper can be diminished by adding a portion of mineral which contains no copper; and when the proportion is so far diminished that the copper can be no longer detected, the operation must be repeated till the operator is successful in again detecting it. When, in this way, several assays have been made for practice, one soon becomes master of the science, which only requires dexterity and a practised eye.

When several metals are contained in the same specimen, they are generally obtained reduced together to a metallic



alloy ; some of them can be obtained singly, e. g. copper and iron, which leave a regulus of each metal. When several metals are mixed together, especial researches are required to determine the nature of the reduced metal. I shall describe, farther on, the reaction of each metallic oxide.

Instead of soda, potash can be used in all these operations ; but soda is always to be preferred, since its carbonate remains dry, while the carbonate of potash attracts moisture from the air, and because the dissolving power of soda is to that of potash as 25.58 to 16.95, that is to say, in proportion to the quantity of oxygen which they contain.

2. *Borax.* The borax of the shops must be dissolved and recrystallized. GAHN often showed me that by melting borax with soda, till both were absorbed by the charcoal, a white metal could be obtained, which seemed to come from the vessels in which the borax is refined. This does not occur with borax which has been recrystallized.

The borax can be kept in small grains of the size required for blowpipe use, or in powder, in which case it can be taken up on the moistened point of the knife, like soda. Some persons use borax from which the water of crystallization has been driven off by ignition, in order to avoid the intumescence which would otherwise take place when the borax is melted on the charcoal. This is certainly convenient, but the borax attracts moisture in process of time, at least on the surface, and begins to puff up, although not so considerably as before. I always use unmelted borax, since the intumescence causes a very trifling inconvenience, and the method of collecting the melted mass into a globule is soon learned.

Borax is used for the decomposition of a great number of substances. The substance intended for examination, is to be placed, in powder or in fragments, according to circumstances, upon the swollen mass, or moistened and made to adhere to the borax bead. In general, it is best first to attempt to decompose a small fragment of the mineral, since if it be used in the form of a powder, the undecomposed particles are with difficulty distinguished from the already separated elements. The following circumstances are to be attended to ; whether the substance is easily or slowly dissolved, with or without effervescence ; whether the bead has acquired a color, and whether this color remains the same in the oxidating and reducing flames ; whether the color is heightened or diminished during the process of cooling ; and, finally, whether the bead remains transparent after cooling, or becomes opaque.

Certain substances have the property of giving a clear glass



with borax, which remains transparent on cooling; but if the bead be gently heated in the outer flame, especially if it be exposed to a fluttering external flame, it loses its transparency, becomes milk-white, and, in certain cases, acquires a color. This is the case, for instance, with the alkaline earths, with yttria, glucina, zirconia, the oxides of cerium, of tantalum, of titanium, &c. For this operation, it is necessary that the glass be saturated to a certain point with the earth or the oxide. It is not the case with silica, alumina, the oxides of iron, of manganese, &c.; and the presence of silica prevents this appearance from occurring in those earths which alone would show it, so that their silicates either do not give this result at all, or only after the glass is super-saturated by them. To avoid circumlocution, I shall describe this operation by saying, that the bead can be *rendered opaque by flaming*, or by the intermittent flame.

The use of borax is founded on the readiness with which the elements of this salt form acid and basic combinations, which are all, to a certain degree, fusible. For this reason, it decomposes bases and produces with them fusible double salts; and also with the acids, among which I reckon silica, and to a certain extent alumina, it forms acid double salts. Since all these salts generally retain their transparency on cooling, the color which is produced by the combination with the decomposed substances is the more accurately observed.

3. *Salt of phosphorus.* This salt is obtained by dissolving 16 parts of sal ammoniac in a very small quantity of boiling water, and adding 100 parts of crystallized phosphate of soda, which must be dissolved together over the fire; the solution is then filtered hot, and allowed to cool slowly, during which operation the double salt forms in crystals. The mother water contains common salt and a certain quantity of the double salt. It does not, however, answer to evaporate again, since the common salt crystallizes with the double salt, which, besides, becomes acid during the evaporation, so that ammonia must be added in order to obtain crystals. If the salt of phosphorus be impure, it gives a glass which becomes more or less opaque on cooling. It must in this case be redissolved, ammonia added, and the double salt recrystallized.

This salt is kept in large grains or in powder. The crystals are often of the proper size for keeping. Put upon the charcoal and submitted to the action of the flame, it boils, puffs up a little, and gives off ammonia; phosphate of soda remains behind, which quickly liquefies, and on cooling becomes a clear, colorless bead. Its efficiency as a reagent depends principally

on its free phosphoric acid, and it is preferred to this, because the phosphoric acid cannot be kept without deliquescing, while at the same time it is much dearer, and is also easily absorbed by the charcoal. The salt of phosphorus shows therefore the action of an acid upon the substance to be tested. The excess of acid takes up all the bases, and forms with them more or less fusible double salts, whose color and degree of transparency must be observed. This flux is especially adapted for detecting the metallic oxides, of which the peculiar color is generally far better determined by its aid, than when borax is used.

This flux decomposes the combinations of the salts, and expels the acids; the volatile substances are driven off in fumes, while the fixed remain behind, and either share the bases with the phosphoric acid, or are separated and swim undissolved in the glass. For this reason, the salt of phosphorus is an excellent reagent for the silicates, from which the silica is separated, and remains as a gelatinous mass undissolved in the melted flux.

4. *Saltpetre*. Long and delicate crystals are to be selected and preserved entire. The use of this reagent is very limited, and its object is to oxidize such assays as cannot be oxidized by the external flame. This is performed by touching the melted flux with the extremity of the crystal of saltpetre; since, however, the bead would get cold before the crystal could be taken up, it must be held ready between the third and fourth fingers of the right hand, while blowing. At the moment that the blast is suspended, the saltpetre is approached to the bead, and held for a moment against it. The melted mass swells, foams, and either becomes immediately colored, or it does not become colored till after cooling. It is best not to continue blowing, since the reaction is best observed in this frothy state of the flux.

This reaction is hardly made use of, except to detect so small quantities of manganese that the bead would not be colored without the action of the saltpetre; but as we possess a better test for this substance, this reagent can be tolerably well dispensed with.

5. *Glass of borax*, is to be kept as a coarse powder. Its use is limited, but it is indispensable in detecting phosphoric acid in minerals, in the way which will be described in the account of the reaction of the salts of the phosphates.

6. *Bisulphate of potash*, in the anhydrous state. It is to be kept in the form of a coarse powder, in a phial well secured from moisture. It is only used in the detection of lithia, bo-

racic acid, and bromine, in the way which will be described farther on.

7. *Gypsum*, and

8. *Fluor spar*, both, free from water, are used mutually to detect each other. They are, on this account, of great value to the mineralogical chemist. If a small fragment of gypsum be placed touching a still smaller fragment of fluor spar; and if they be heated together, they begin to melt at the points where they touch each other, gradually become absorbed into each other, and easily melt to a clear, colorless glass bead, which cools into a milk-white enamel. In this way the two substances are used reciprocally to detect each other. This fused combination seems to be a double salt of the sulphate of lime and the fluor spar; and since it is always necessary, in order to obtain a clear bead, to take a larger volume of gypsum than of fluor spar, it appears probable that the double salt is composed of one atom of each. If a considerable proportion more of one than of the other be taken, the fusion is incomplete. If the fused mass be heated strongly for some time, or if it be melted in the reducing flame, it fixes, swells up, becomes angular, and cannot be again melted. The reason of this seems to be, that the sulphuric acid is decomposed, sulphurous acid formed, and the double salt destroyed. In the same way, sulphate of baryta and sulphate of strontian may be fused with fluor spar, and fluoride of barium and fluoride of strontium with gypsum.

9. *Nitrate of cobalt*, dissolved in water. This solution must be quite pure, free from alkali, and slightly concentrated. I keep it in a small phial, made of glass tube, which is figured in Pl. II. Fig. 29, and which, to be better protected, is inserted in the cylinder used for boring cavities in the charcoal, after lining it with a piece of cloth, so that the glass may not touch the metal, and that the phial may fit perfectly. It is closed with a cork, into which a bit of platina wire is inserted, the end of which is hammered out into a sort of small spoon, so that a drop of the liquid may be taken out upon it.

The object of this reagent is to distinguish alumina and magnesia from each other. The first named of these substances gives a fine blue color on being strongly heated with the oxide of cobalt, and the latter a pale rose-red. Silica does not prevent this reaction from taking place. This operation is performed in two ways.

a. A fragment of the unpulverized assay is used in case it will absorb the cobalt solution, when a drop of the latter is to be put upon the former, and the whole is strongly heated, but not

fused. In a short time the assay acquires a color. If blue, more or less clear, it indicates the presence of alumina; if, on the other hand, it be red, or pale rose color, it indicates the presence of magnesia. In the latter case an attempt must be made to melt the assay, since the red color is retained and rendered more apparent by fusion. The alumina retains its blue color on being fused, but minerals which contain lime or an alkali without alumina, and which before fusion do not show this blue color, after fusion give a blue glass with the nitrate of cobalt.

b. If the substance be harder, a crystallized mineral, for instance, the following course must be adopted. The mineral is to be finely pulverized with water, in the small mortar, and the pestle is then to be lifted directly out of the mixture, so that a drop remains adhering to it, which drop contains the finest portion of the substance. This drop is to be placed upon the charcoal, which absorbs the water, and leaves a half dry mass spread out upon its surface. A drop of the cobalt solution is to be added, and the whole heated, first by the spirit-lamp, and then with the blowpipe flame, to ignition. No regard need be paid to the changes of color, from blue to red, which take place before the matter is decomposed, and which end in a dark color. It is only after a still stronger heat has been applied, that the desired reaction makes its appearance. When it is seen that the mass begins to separate itself from the charcoal, it can be carefully taken in the platina forceps, and be thus more easily brought to the proper temperature.

The color of the assay can only be properly judged, after it is perfectly cool, and by daylight. By the light of a candle the clearest blue appears often of a dirty violet color.

How much of the cobalt solution may be necessary, depends on its degree of concentration. This is easily learned by experience. The presence of the metallic oxides in the assay destroys the action of this reagent. Traces of saltpetre also change the nature of the reaction, so that it gives a blue color with substances with which it otherwise would not, e. g. with silica and zirconia.\*

\* This reaction was discovered by Gahn, long before the cobalt blue color of the arseniate and phosphate of cobalt with alumina was discovered by Thénard. This led Gahn to the discovery of the same blue color, which he prepared from the alumina precipitated from alum and free from iron, to which he added a concentrated solution of the oxide of cobalt in nitric acid, on which the whole was dried and strongly ignited; but as Gahn found that this beautiful blue color was disagreeable to the eye by candle-light, he thought that it could not be used, and that it was not worth description. He hit upon the use of this reagent in the course of a series of experiments, which he

*Oxalate of cobalt* can also be used for this purpose. It is more easily kept and carried about, as it is in the form of a dry powder. The mineral is to be pulverized exceedingly fine, and mixed with a gradually increasing quantity of oxalate of cobalt, while, after each addition of the latter substance, a portion of the assay must be submitted to the action of the flame. In this way the proper proportion of the salt of cobalt for producing the blue color is hit upon. It is necessary to heat the assay with the oxide of cobalt for some time.

10. *Nitrate of nickel, or oxalate of nickel.* I prefer the latter, since it can be most easily carried about in the form of a powder. The nitrate, however, when dissolved, can be more conveniently used. It is used to detect potash, according to the observation of LAMPADUS, that a soda glass is colored brown by the oxide of nickel, while the potash glass, on the other hand, acquires the bluish-purple color of the solution of the oxide of nickel in ammonia. The oxide of nickel must be quite free from cobalt: it is to be tested by treating it with borax, with which it should give a brown and not a blue bead.

11. *Tin.* For this purpose tin foil is to be preferred, either cut into small strips, or, still better, into long pieces half an inch in width, which can be rolled together. The object of the tin is to produce the highest degree of reduction in the glass fluxes, especially when the substance contains a minute quantity of a metallic oxide, which can be reduced to a protoxide, and thus give a more satisfactory result. The bead, previously heated in the reducing flame, is to be touched with the end of the tin foil, which operation leaves a particle of melted tin upon the flux, which is in an instant fused by the reducing flame. It is not necessary to blow for a long time, since the tin might entirely precipitate the metal to be reduced to the state of protoxide, in which case all reaction ceases. The tin may also be dissolved in so large a proportion in the salt of phosphorus, as to render the bead opaque.

12. *Iron,* in the form of piano wire of No. 6, 7, or 8. BERGMAN and GAY used iron to precipitate metals from the different fluxes, or to separate them from sulphur, or from the fixed acids. The metals which can be separated and detected in this manner, are copper, lead, nickel, and antimony. For the purpose, a bit of the wire is to be inserted into the fused assay, and the blowing continued, on which the iron becomes

covered in order to determine what changes mineral substances undergo, when dried and heated with metallic solutions. Of all the substances which he tried, cobalt was the only one which gave a useful result.

coated with the reduced metal, and which often collects in the form of small globules on the edge of the flux. Iron has acquired, however, a still more important application, which is founded on the property it possesses of reducing the phosphoric acid of the phosphates to phosphorus, and forming phosphuret of iron, which fuses in the flux to a white, brittle and metallic globule. I shall describe, farther on, in what manner the operation is to be performed.

13. *Lead*, free from other metals, especially silver, for cupellation.

14. *Bone ashes*, are used in the cupellation of metals containing gold or silver, or their ores. GAHN used small cupels, of one-fourth of an inch in diameter, which, laid one against another, could be kept in a cylindrical case. I have concluded that it is best to prepare them in the following manner. The bone ashes are to be kept finely powdered, or, still better, levigated, in the box with the other reagents. When wanted for use, they are to be taken out on the point of the knife moistened in the mouth, and mixed with a small quantity of soda, in the left hand, to a stiff paste. A hole is then to be made in the charcoal, which is to be filled with this paste, and the surface smoothed by pressing it with the agate pestle. It is then to be slowly heated by the flame of the blowpipe, or, still better, by the spirit-lamp, till perfectly dry. The soda serves to make the mass coherent, but it can be dispensed with. The lead, melted with the assay, is then to be laid upon this small cupel and heated in the exterior flame, till the precious metal remains alone upon the cupel. This test is so sensitive, that a globule of silver may always be obtained from the lead of commerce, which can be seen without a magnifying glass. I have even been able to take hold of them and hammer them out.

I have seen pipe-stems used for the same purpose, the cupellation being performed upon a cross section of the same; but these do not absorb a sufficient quantity of the oxide of lead, and allow of the cupellation of only a very small quantity at once, so that the grain of silver is smaller in proportion. I endeavored for some time to use burnt cylindrical bones for this purpose. I performed the cupellation on a part near the end, and at each operation I removed the part already saturated with the oxide of lead. But the fragility of the burnt bones is so great, that the former method is far preferable.

15. *Silicic acid*, as obtained from the operations of chemical analysis, or finely pulverized rock crystal. It is used to form with soda an easily fusible glass, to test the presence of sulphur or sulphuric acid, in case the assay does not contain

silicic acid, with which the soda can form a glass. I sometimes use glass instead of silica, but this mixes less readily than the pure silica with the soda, when they are fused together. See the article on the sulphates.

16. *Oxide of copper*, is used for detecting chlorine.

17. *Test-paper*, colored with litmus, Brazil-wood, and turmeric, cut in small strips, and preserved, according to circumstances, in round or flat boxes.

18. *A piece of silver foil*, for the reaction of hepar or soluble sulphurets.

19. *Formate of soda*, anhydrous, is used for detecting arsenic in the oxide of antimony.

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#### VIII. GENERAL RULES FOR BLOWPIPE TESTING.

It often happens, in the course of the operation, that the assay, with which one has been for some time occupied, loosens itself from its support, and is blown away by the current of air. To recover the fallen substance, GAHN placed his blowpipe lamp in a large tray of sheet iron, with edges turned up about one inch, and covered the bottom with thick paper. The advantage of this arrangement is, that the substance, when it falls, is caught by the tray, and is easily seen upon the white paper. If the iron be tinned and the bead red hot, it may easily melt a portion of the tin, by which, changes in the nature of the results might be produced, on which the operator did not calculate. In travelling, shallow plates of porcelain or crockery ware can be used, or a sheet of paper, with turned-up edges, can be used in their place. Between the several operations the paper must be brushed, that no beads may remain lying upon it to produce confusion.

In regard to the size of the assay, the general rule is, that it is large enough, provided the nature of the result which is expected can be distinctly seen, and that the operator is more likely to fail by using too large, than too small an assay. VON ENGSTRÖM prescribed a fragment one-eighth of an inch square. This would perhaps do for operations made with the glass-blower's lamp, but it is far too large for use with the mouth-blowpipe. BERGMAN recommended the assay to be of the size of a pepper-corn, but added that very small quantities must often be operated on. A piece as large as a pepper-corn, is, in

many cases, more than enough for all the researches which are to be made on a substance, and rarely can so large a mass be properly treated in the blowpipe flame. It is even much too large for the glass of the flux. A piece of the size of a common mustard-seed is often quite sufficient. However, experience soon teaches what is the most convenient size, especially if one attempts an operation on a small quantity, which he has been unable to succeed in when employing a larger fragment; and, in general, it may be remarked, that, if the result be obtained with a large assay, the operation requires a longer time, and more exertion in blowing, while the degree of fusibility, and the color, are as well seen in the smaller assay as in the larger. The only case in which advantage may be derived from the use of a large assay, is where a metal is to be reduced by soda, or by cupellation, where naturally a larger quantity of the metal is obtained, which can then be more easily tested and examined.

Before the assay is exposed to the action of the fluxes, it is necessary to examine its behavior alone before the blowpipe. This operation is thus performed: a. the assay is heated in a glass tube over the spirit-lamp, to see if it decrepitates or gives off water or other volatile matter; b. it is to be gently heated upon the charcoal by the blowpipe flame, and then held to the nose the moment it is withdrawn from the fire, by which means the presence of the volatile acids, arsenic, selenium, and sulphur is detected; the difference of smell in the reducing and oxidating flames must be also taken into account, since sulphur and selenium are best detected by the oxidating, arsenic by the reducing flame; c. its fusibility is examined. If it be a substance of which only round grains are to be had, it is best to lay it upon the charcoal, although it may be easily driven away by a strong blast, particularly if infusible. If, however, the fragment for examination can be selected, a quite thin splinter must be broken off with the hammer from the edge of the specimen, and held in the platina points of the forceps, with the sharpest end exposed to the flame. It is then easily determined whether it be fusible or not. The infusible substances retain their edges unaltered, and, with the magnifying-glass, the question is settled in a moment. The difficultly fusible become rounded on the edges, while the easily fusible melt together into a globule. Very difficultly fusible minerals I generally pulverize with water, and let fall a drop of the mixture upon the charcoal, exactly as in the operation with the nitrate of cobalt, when the mass is dried and heated in the outer flame till it separates from the coal. It forms then a



coherent disk, which is to be taken carefully with the platina tongs, and heated on the extreme edges, with the strongest flame which can be produced. The edges of the infusible minerals are generally bent together a little, a proof that the substance is not absolutely infusible; but the magnifying-glass shows at once whether the assay be vitrified or not. Dry, pulverulent substances are to be made into a paste, and spread out upon the coal with the point of the knife, and the blowing proceeded with as before.

I am convinced that the temperature produced by the blowpipe, fed by air from the lungs, has a distinctly defined limit; so that, for instance, alumina or silica cannot be melted, however small fragments of them may be employed; and that the observations with regard to the fusibility or infusibility of different substances do not depend so much on the size of the assay and the skill of the operator as has been generally supposed. For this reason, the mouth-blowpipe has a decided advantage over the blowpipe in which oxygen gas is used.

H. DE SAUSSURE performed a set of experiments to determine the relative degrees of fusibility of different minerals; and he reckoned the temperature, at which they melt, in degrees of Wedgwood's pyrometer, according to the diameter of the largest assay which he was able to melt, compared with the diameter of the largest globule of silver melted in the same way, of which the degree of fusibility was previously determined. These experiments are of considerable value, but cannot properly be used as a means of discriminating minerals, and the results could be but approximations. I therefore pass them by.

Certain bodies, especially minerals, change their appearance and form considerably in the blowpipe flame, without melting; some puff up like borax, others form cauliflower-like excrescences; and, of these, a part melt, after swelling out, and others remain in that state without being fused. Some foam and melt, and form a blebby glass, which is rendered more or less opaque from the numerous bubbles which it contains, although the mass of glass is itself transparent.

This puffing up and foaming takes place, in most minerals, at the temperature at which all the water is driven off. The cauliflower-like ramifications seem to be caused by a change in the relative position of the elements, produced by the heat; but the intumescence, which takes place in the fused mineral, seems to be caused by the escape of a gaseous constituent of the assay, although it often takes place in substances in which analysis shows no trace of such an element. It often

takes place in silicates of lime, or of an alkali with alumina. It sometimes disappears for an instant, but soon commences again, and continues so long as the assay is kept at the melting point. In this last case, the reason seems to be, that the assay takes carbonic acid gas from the flame, which, by contact with the coal, is reduced to carbonic oxide, and escapes in bubbles. The cause of these peculiar phenomena deserves to be more fully investigated, since the knowledge of these substances cannot be considered perfect so long as this is not understood. In the mean time, this reaction serves to distinguish substances which resemble each other.

In using the fluxes, the blast must not be too soon suspended; that which first seems insoluble, is often by degrees taken up, and, after some time, fully dissolved. Furthermore, the flux must be added in small quantities, and this operation must be repeated till the exact point of saturation is reached. When the fluxes are operated with in the reducing flame, it often happens that the bead becomes oxidized in the short space of time required for it to cool, which renders the operation uncertain. In this case, the coal must be turned over, and the still liquid globule be allowed to fall upon a cold body, as, for instance, the tray; or, if that does not answer, a drop of oil can be put upon it, by which it is cooled, though it often happens that the oil is carbonized and the glass rendered opaque, which must, if possible, be avoided.

When the color of a flux is so deep that it appears black, it is customary to hold the bead against the flame of the lamp, in such a direction that its image appears inverted in the bead with the color of the glass. The bead also may be pressed flat with the smooth surface of the forceps before it hardens; or, if that is not sufficient, the bead must be drawn out to so fine a thread, at the moment of its cooling, that its color can be recognized.

Furthermore, substances treated in the outer and inner flame, as well as when fused alone and with the fluxes, offer a variety of appearances which deserve notice, and which must all be taken into consideration, in summing up the result of each experiment. Attention must be given to the most trifling circumstances, since such may lead to unexpected results. Furthermore, the conclusions which can be obtained in regard to entirely unknown substances, investigated by the aid of the blowpipe, depend entirely on a general knowledge of chemistry, and especially on an accurate acquaintance with the phenomena of the blowpipe, and also upon the personal skill of the observer in recognizing the most characteristic reaction, and in

following it up ; no general rule can be given in regard to this subject. When in the course of investigation with the blowpipe, the results are to be described either for the benefit of one's self, or of others, two series of observations must be made and separately described ; since in such cases it may often happen, that that which escaped notice the first time may be evident upon a second examination. It is still better, however, that two persons should each go through the same series of experiments, and draw up their results for comparison ; if they agree, it may, with reason, be concluded, that they are correct ; in the contrary case, the cause of the disagreement must be studied out. Here difficulties often are occasioned by the different manner in which different observers see and describe colors. Thus, for instance, GAHN sometimes called a shade of color, yellow or dark yellow, which I should have called red, although we both agreed in naming the fundamental colors yellow or red.

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## IX. BEHAVIOR OF SUBSTANCES BEFORE THE BLOWPIPE.

It cannot here be a question with regard to the simple, non-metallic bodies. They are in this state easily recognized, and the knowledge of their properties must be taken for granted in those who are occupied in such researches. Neither are the oxides and acids properly objects of investigation before the blowpipe, unless in combination with other oxidized bodies, and they will, therefore, be treated of in the description of the salts farther on.

I will, therefore, commence with the metals proper, and especially their oxides, among which I reckon the alkalis and earths, and I will give the results of my experience in the determination of them.

### A. ALKALIES, EARTHS AND METALLIC OXIDES.

#### 1. ALKALIES.

The alkalis cannot be recognized with perfect certainty by the action of the blowpipe. In their free or carbonated state, their taste, and their action on reddened litmus paper, is the best test for them. As salts, they are best detected by fusion with soda on

the platina foil; if no precipitation takes place in the fused mass, the basis of the salt is an alkali.

Baryta and strontian give a clear bead, but if the melted mass be dissolved in water, they are easily detected, since the carbonates of these earths remain behind undissolved.

To distinguish the alkalis from each other, the point of the blowpipe flame must be observed. This flame ends in a pointed, feebly illuminating edge, which is often colored by various volatile substances. If, for instance, carbonate or nitrate of potash be melted into a bead on the platina wire, the flame is tinged with violet behind the bead. With a soda salt, it is yellow, with a lithia salt, red. This reaction can, however, be rarely used for the detection of potash, since a minute proportion of soda tinges the flame yellow, and entirely destroys the peculiar action of the potash on the color of the flame. When, for instance, saltpetre contains only one per cent. of soda, the flame acquires a yellow color, and, in nature, potash seldom occurs without a mixture of soda.

HARKORT used, for the detection of potash, the observation of LAMPADIUS, that potash glass is colored blue by the oxide of nickel; soda glass, on the contrary, brown. This is, to a surprising extent, true. Nothing more is necessary than simply to dissolve the oxide of nickel in borax, and to add to the brown glass a very minute quantity of saltpetre, felspar, or any other substance containing potash, when a blue glass is obtained. The presence of soda does not impede this reaction. To produce this blue color, care must be taken that no more oxide of nickel be dissolved in the borax than the potash is capable of saturating; for an excess brings out the brown color of the soda, by which the weaker blue is overpowered. The operation succeeds best when the color of the borax glass is very faint. More and more of the assay is to be added, and if it contains potash, a blue bead will at length be obtained.

The yellow color which soda imparts to the blowpipe flame, although always well marked and evident, is not to be trusted to as a means of detecting this alkali, since it may be produced by a variety of causes.

Lithia is distinguished from the foregoing, in that when it is melted upon platina foil, this alkali leaves a yellow stain around the spot which it covered; this reaction is not produced by lithia salts, unless soda be added, which separates the lithia, which then acts upon the platina. This reaction is not to be depended upon as a test for lithia, since, although it takes place most decidedly when a salt of lithia is present, it is also produced by substances which do not contain lithia, when they are heated

with soda, and even the soda itself sometimes leaves a trace upon the platina. This is not the case with potash, which, on the contrary, has the disadvantage, that, added in excess, it destroys the reaction even if lithia be present. This spot upon the platina disappears if washed and ignited; but the metal loses its polish and becomes dull, which can easily be seen when the platina is heated.

CHR. G. GMELIN noticed that lithia imparted a red color to the point of the blowpipe flame, if directed upon that alkali. TURNER showed that this reaction can be produced in the silicates containing lithia, if 1 part of finely pulverized fluor-spar be mixed with  $1\frac{1}{2}$  parts of sulphate of ammonia, or bisulphate of potash, and the substance be melted with it. When the ammoniacal salt is used, the flame is at first green and then red. If a potash salt be used, and the assay contains no lithia, the flame is of a faint violet color; if, on the contrary, it does contain lithia, the flame is red.

Ammonia is seldom tested for by the blowpipe. The substance needs only to be mixed with soda, when the peculiar smell detects the ammonia at once, or the mixture can be warmed in a small matrass, when carbonate of ammonia sublimes. The assay can also be heated in a closed tube, in which a moistened piece of weakly reddened litmus paper is placed.

## 2. BARYTA.

*Alone*, it does not fuse, unless it has absorbed water which was formed by the flame. The *hydrate* melts, boils and swells, and ends by congealing on the surface and sinking into the charcoal, where it becomes anhydrous, and forms a hardened mass. *Carbonate of baryta*, melts readily into a transparent glass, which becomes enamel-white on cooling. On charcoal, it boils violently, spirts about, becomes caustic, and is absorbed by the charcoal, like the hydrate. With the following fluxes they both react in the same manner as the pure earth.

Baryta is dissolved by *borax* into a transparent glass. An addition of a larger quantity gives a transparent glass, which on cooling becomes covered near its base by warty excrescences of a milk-white substance. A still larger quantity produces a glass, milk-white at the base, which becomes finally enamel-white throughout. The glass, which is transparent on cooling, can be rendered opaque by flaming.

It is easily dissolved with effervescence by the *salt of phosphorus*, in which operation the bead foams, swells, and finally

shrinks together into a transparent glass. On the addition of a larger quantity of baryta, a transparent glass is obtained, which, on cooling, becomes spotted with milky-white, and if still more be added, the bead on cooling becomes enamel-white. It melts with *soda*, and is absorbed by the charcoal.

With *nitrate of cobalt* it melts to a bead, which, as long as it is still hot, is, according to the quantity of cobalt, brownish-red, brick-red, or rusty-yellow; on cooling, it loses its color. On being again heated, the color is not restored, unless the bead be again melted. It is soon reduced to a light grey powder on exposure to the air.

### 3. STRONTIAN.

*Alone*, the *hydrate* behaves like that of baryta. The *carbonate of strontian* melts, however, at a certain, not too elevated, temperature, but only on the edges, and begins immediately to swell out in cauliflower-like ramifications, which emit a brilliant light, and which, when strongly heated in the reducing flame, impart to it a faint reddish tinge, which, however, is hardly to be seen by daylight. These ramifications have an alkaline taste and reaction.

With *borax* and *salt of phosphorus* it behaves exactly like baryta.

Caustic strontian is not dissolved by *soda*. Carbonate of strontian, mixed with an equal volume of soda, fuses into a transparent glass, which becomes milk-white on cooling. In a stronger heat, the mass begins to boil, becomes caustic, and is absorbed by the charcoal. A larger addition of carbonate of strontian is not dissolved, but is rendered caustic, and is absorbed by the charcoal.

With the *solution of cobalt* it gives a black or greyish-black color, and does not fuse like baryta.

### 4. LIME.

*Alone*, caustic lime undergoes no change. Carbonate of lime is rendered caustic, and then looks whiter, emits a more brilliant light, and falls to a powder when moistened. Salts of baryta and strontian sometimes contain lime. To detect this they must be melted on platina foil, when the lime remaining undissolved renders the bead opaque. Melted on charcoal with a sufficient quantity of soda, baryta and strontian are absorbed into the coal, and leave the lime as a thin coating on its surface.

It is easily dissolved by *borax* to a clear bead, which can be rendered opaque by flaming.

The carbonate of lime is dissolved with effervescence. An addition of a still larger quantity, produces a transparent glass, which, on cooling, crystallizes and becomes angular, although not so distinctly, as, for instance, the phosphate of lead. The glass is never so milk-white as that of baryta or strontian.

It is dissolved in large quantity by the *salt of phosphorus* (the carbonate with effervescence) to a clear glass, which, on cooling, remains transparent. If more carbonate be added in small fragments, the carbonic acid is driven off, and the fragments become changed to phosphate of lime, without altering their form. After blowing for some time, this also begins to melt, and, on cooling, delicate acicular crystals shoot through the glass upon the undissolved portion. If the glass be fully saturated, it becomes, on cooling, quite milk-white.

Lime is not particularly easily dissolved by *soda*, either in its caustic state or as a carbonate. The soda is absorbed by the charcoal, and leaves a semi-spherical mass of lime upon its surface. With the *solution of cobalt*, lime gives a black or grey-black unmelted mass.

## 5. MAGNESIA.

*Alone*, no change takes place. It restores the color of moist reddened litmus paper.

It behaves with *borax* like lime, but does not become so strongly crystalline.

It is easily dissolved by the *salt of phosphorus* to a clear glass, which, if saturated with magnesia, becomes milk-white on cooling. The imperfectly saturated glass is rendered milk-white by flaming.

It is not attacked by *soda*.

With the *cobalt solution* it produces, after long-continued blowing, a beautiful rose-red color, which is not, however, intense, and which cannot be properly seen till the assay has become cool.

## 6. ALUMINA.

*Alone*, it remains unchanged.

By *borax* it is slowly dissolved to a transparent glass, which does not become opaque on cooling or by flaming. If a large proportion of alumina in fine powder be added, an opaque glass is obtained, whose surface becomes crystalline on cooling, and

which scarcely melts again. This glass is opaque when hot or cold, and if the bead is transparent when melted, it remains so on cooling.

By the *salt of phosphorus* it is dissolved into a clear bead, which does not become opaque at any degree of saturation. If too much be added, the glass loses a part of its transparency. Saturated salt of phosphorus mixed with the saturated borax glass still remains clear.\*

With *soda* it swells out and forms an unmelted combination, while the excess of soda is absorbed by the coal.

With the *cobalt solution*, it produces, after strong heating, a fine blue color, which becomes still deeper if more of the cobalt solution be added, but is still a fine blue. It only appears properly blue by daylight and when cold.

#### 7. GLUCINA.

*Alone*, it remains unchanged.

It is dissolved in large quantity by *borax* and the *salt of phosphorus* into a transparent glass, which is rendered opaque by flaming. If a larger quantity be added, it becomes, on cooling, milk-white.

It is not attacked by *soda*.

With the *cobalt solution*, it gives a grey or dark-grey mass.

#### 8. YTTRIA.

What up to this time has been called yttria, consists, according to the researches of MOSANDER, of three separate earths : a, yttria proper, b, terbia, and c, the proto-peroxide of erbium. The yellow oxide of erbium becomes white in the reducing flame, and acquires a transparent yellowish appearance, without retaining so deep a yellow color after cooling as it had before. It becomes milk-white in borax and salt of phosphorus, and is somewhat slowly dissolved into a colorless glass. The borax glass behaves as was described under glucina. Treated with soda it becomes white, without dissolving.

#### 9. ZIRCONIA.

*Alone*, as prepared by the ignition of the sulphate of zirconia, it emits a more brilliant light than any other substance ;

\* The glass which is rendered milk-white by flaming, also loses its transparency if the bead of the salt of phosphorus be mixed with borax.



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the whole room is illuminated, and so great is the power of the light, that the eye can scarcely endure it, even by daylight. It is, however, entirely infusible. KLAPROTH says that zirconia becomes sintered before the blowpipe, but in this case it could not have been pure.

Its behavior with *borax*, *salt of phosphorus*, and *soda*, is like that of glucina, with only this difference, that it is more slowly dissolved by the salt of phosphorus, and sooner gives an opaque bead.

### 10. THORINA.

*Alone*, on charcoal, this earth does not fuse, or alter its appearance in any way.

By *borax* it is very slowly dissolved; the bead is transparent and colorless, and is not rendered opaque by the intermittent flame. By saturation, it arrives, at last, at a point where it becomes of itself milky on cooling.

It is very slowly taken up by the *salt of phosphorus*.

It is not at all acted on by *soda*.

### 11. SILICA.

*Alone*, it remains unchanged.\*

By *borax* it is very slowly dissolved, and gives a transparent and difficultly fusible glass, which is not rendered opaque by the intermittent flame.

It is dissolved in very small quantity by the *salt of phosphorus*. The glass remains clear, on cooling. The undissolved portion is semi-transparent.

*Soda* dissolves it, with effervescence, to a clear glass. With the *solution of cobalt*, it gives, at a certain degree of saturation, a bead of a faint blue color, which, on the addition of a larger quantity of cobalt, becomes black or dark grey, by which it is easily distinguished from substances containing alumina. If an intense flame be directed upon a thin edge of the assay, it melts with the cobalt to a blue glass, and the border around

\* H. DE SAUSSURE announces, that he melted silica (rock-crystal), supported on a slip of cyanite, by means of the flame of a thick wax candle, supplied with a blast of air from a double bellows, having a surface of 62 square inches. The bead had the diameter of 0.014 of a line. I could not produce the smallest sign of melting, either on the coal or in the forceps, in the thinnest edge of a fragment of silica, and I suspect that in De Saussure's experiment, the support may have produced an effect on the assay, and that the air supplied by the bellows, being purer than that of the lungs, may have also contributed to effect a result which cannot be obtained with the mouth-blowpipe.

the melted part remains also blue, but this blue has a tinge of red, and is not a fine color.

I direct the reader in regard to the action of silica, to the article on the silicates, farther on.

## 12. THE ACIDS OF ARSENIC.

*Arsenic acid*, heated on charcoal, gives off the peculiar smell of arsenic. Strongly heated in the matrass, arsenious acid sublimes, and oxygen is given off.

*Arsenious acid* is easily sublimed in the matrass or open tube. The crystals, examined by the microscope, are generally regular octahedra.

If a glass tube be drawn out, so that its diameter be not greater than that of a knitting-needle, and the fine tube be sealed at the end, and arsenious acid be introduced into this part of the tube, the arsenic can be reduced, if a small splinter of the charcoal be inserted into the tube till it nearly touches the bottom. That part of the tube in which the charcoal lies must be heated till the coal is ignited, which is best done by the flame of a spirit-lamp, and then the end of the tube, where the arsenic lies, must be brought into the flame, so that the acid shall come in contact with the ignited coal while in the gaseous state; it is then reduced, and condensed metallic arsenic is deposited in the forward part of the tube. It is better to make use of a long continuous splinter than to use powdered charcoal, since this is liable to fall out of the tube. If the amount of arsenic be trifling, the tube is only blackened at a little distance from the spot on which the flame was directed. This part of the tube is then carefully to be introduced into the flame, and the sublimed arsenic is to be collected into a narrow ring, which then has a metallic lustre. The tube is then to be cut off on both sides of the ring, grasped with the forceps, and heated at a little distance from the nose. The arsenic can be recognized by its smell, and thus it cannot be mistaken for tellurium, antimony, mercury or cadmium. Few tests can be so decisive as this, where so small a quantity of the metal is operated on. A grain of arsenious acid, if it be large enough to be removed from its place to the bottom of the tube, is sufficiently large to give a satisfactory result. Of course, the smaller the grain of arsenic, the finer the tube must be drawn out.

In order to be convinced of the arsenical smell of the arsenious acid upon the charcoal, it must be mixed with soda before being subjected to the blowpipe flame; since the arsenious acid,

when heated alone, often volatilizes before any part of it is reduced, and the vapor of arsenious acid has no arsenical smell. See further on, under the head of the arsenical metals and sulphuret of arsenic.

### 13. VANADIC ACID.

*Alone*, on charcoal, it fuses, and is reduced to the state of suboxide, while a part of the acid is absorbed by the coal, and the reduced portion is kept upon the surface. This resembles in appearance graphite.

On platina foil it melts to a deep yellowish red liquid, and becomes crystalline on cooling.

It is easily dissolved by *borax* and *salt of phosphorus*.

The glass is yellow in the oxidating flame, but in the reducing flame, especially on charcoal, it gives a fine green, as beautiful as that of the oxide of chrome. When the bead is strongly colored, it has, while still warm, a brown color, and the green color appears only after the bead has become entirely cold. Vanadic acid is distinguished from the oxide of chrome, principally in that its glass becomes yellow on platina, in the oxidating flame, which is not the case with chrome.

It is dissolved by *soda*, and absorbed by the charcoal. Nothing metallic is obtained, in this case, by pulverizing and washing.

### 14. MOLYBDIC ACID.

*Alone*, in the inclined tube, it melts and gives off fumes. The fumes condense on the glass partly as a white powder and partly as brilliant, faint yellowish crystals, directly over the fused mass. On platina foil it melts and fumes. The melted mass is brown, and becomes on cooling pale yellow and crystalline. In the reducing flame it is absorbed by the charcoal; the metal is partially reduced if the flame be sufficiently hot, and can be separated afterwards by pulverizing and washing the charcoal. It is obtained in the form of a grey metallic powder. If a large quantity of the assay be treated in the reducing flame, a copper-red spot of the oxide of molybdena remains upon the charcoal, which is surrounded by a ring of sublimed molybdic acid.

It is dissolved by *borax*, upon the platina wire, and in the outer flame, to a clear, colorless glass. On charcoal, in the reducing flame, the color of the bead is dirty brown, and translucent, not unlike that produced by a mixture of the protoxide

and peroxide of iron. If more molybdic acid be added, the bead loses its transparency entirely in the reducing flame, and a number of brown flocks of the oxide of molybdena may be seen in it, apparently surrounded by a transparent brownish glass.

It is dissolved, by *salt of phosphorus*, on the platina wire, and in the outer flame, to a transparent glass, which inclines to green as long as it remains hot, but on cooling becomes colorless. In the reducing flame the glass is dark and opaque, but, on cooling, it becomes clearly and beautifully green, almost like the oxide of chrome. This shade of color is obtained upon charcoal both in the interior and exterior flame, especially if the proportion of molybdic acid be large. Brown molybdic oxide cannot be precipitated, in the reducing flame, by the salt of phosphorus. Even by the aid of tin the color of the green reduced glass is not changed, but it can be seen that the tin inside of the bead swells, and becomes to a certain extent charged with molybdena.

Molybdic acid fuses with *soda*, on the platina wire, to a clear bead, which becomes milk-white on cooling. If the glass contain a small proportion of molybdic acid, and be heated in the reducing flame, it acquires nearly the same color as the borax glass, under the same circumstances, but on cooling it becomes clouded. If, on the contrary, it be super-saturated with molybdic acid, and subjected to a strong reducing flame, the molybdena is partially reduced to an oxide, and partly to the metallic state, and if the mass be dissolved in water, a greyish-brown heavy substance remains behind, which, when burnished, shows a metallic lustre, and an iron-grey color.

Treated with soda on charcoal, the melted mass is absorbed, and if afterwards the mass be tested, a quantity of reduced molybdena is obtained, in the form of a steel-grey powder. When a new portion of molybdic acid, with a small quantity of soda, is laid upon the spot where the mass was absorbed, and submitted to a strong reducing flame, the portion last added is not absorbed, but a bead is obtained which consists of reduced molybdena, mingled with molybdate of soda, which need only be dissolved to obtain the reduced metal. Molybdena, therefore, contrary to the common opinion, belongs to the easily reducible metals, although it cannot be fused.

## 15. TUNGSTIC ACID.

*Alone*, it becomes black in the reducing flame, but does not fuse.

It is readily dissolved by *borax*, on the platina wire, in the exterior flame, to a clear and colorless glass, which is not rendered opaque by flaming. If added in larger proportion, it loses its transparency when subjected to the intermittent flame, and with a still larger proportion it becomes enamel white, on cooling. In the reducing flame, with a small proportion of the tungstic acid, the glass is yellowish, and the color deepens as it grows cold. If a larger proportion be added, the glass is deep yellow, and, on cooling, clear blood-red. On charcoal this reaction is produced with a trifling proportion of tungstic acid. If tin be added, the glass becomes, on cooling, milk-white.

Tungstic acid is dissolved by the *salt of phosphorus* in the exterior flame into a colorless or yellowish bead. In the reducing flame the glass acquires a fine and clear blue color, finer even than that of cobalt. If the acid contain iron, the glass acquires an entirely different color in the reducing flame; it becomes blood-red, much like the reduced borax glass. The addition of tin destroys the reaction of the iron, and the glass acquires a green or often a blue color; for this purpose it must not be too concentrated; if it is, it can be remedied, however, by the addition of a still larger quantity of the flux.

By *soda*, tungstic acid is dissolved, and gives a transparent dark yellow glass, which, on cooling, crystallizes and becomes opaque white or yellow. This glass retains its bead-like form upon the charcoal. It acquires a still darker color in the reducing flame, so long as it remains hot; but after cooling it becomes again white.

When tungstic acid is treated upon charcoal, with a very small proportion of soda, a steel-grey metallic slag is obtained. If this be washed in the mortar, a large quantity of metallic tungsten, in the form of a steel-grey powder, is obtained, which has a perfect metallic lustre, where it is flattened by the pestle. If tungstic acid be melted with such a proportion of soda that it shall all be absorbed into the charcoal, and then strongly heated, a number of small metallic particles are obtained, which vary in color from a gold-yellow to a pinchbeck-brown. This is the combination of the oxide of tungsten with soda, described by WÖHLER.

## 16. OXIDE OF CHROME.

*Alone*, unchanged.

*Borax* dissolves it slowly, and the bead acquires a beautiful emerald-green color, which is particularly apparent when the

glass is cold. This color can be mostly driven off on the platina wire, in the external flame. The glass becomes, in that case, yellowish-brown, as long as it remains hot; when cool, it inclines to green.

By the *salt of phosphorus* it is dissolved in the exterior as well as the interior flame, and acquires a green color, which becomes very deep if a large proportion of the oxide of chrome be used. If more of it be added to the glass than can be dissolved, and the whole be strongly heated, it acquires the peculiar property of puffing up, more or less, at the moment of liquefaction, and is converted into a foamy mass by some development of gas, which takes place at that moment. If the glass be melted, the foam fuses together, but returns again on cooling. This happens both in the exterior and interior flame, on charcoal or on the platina wire. I cannot discover the cause. It does not take place if the glass be transparent.

*Soda* dissolves the oxide of chrome in the exterior flame, and forms a dark brownish yellow glass, which on cooling becomes opaque and yellow. In the reducing flame the glass is opaque, and, after cooling, green. It is absorbed by charcoal, but I could discover no trace of a reduced metal.

## 17. ANTIMONY AND ITS OXIDES.

*Metallic antimony* is easily melted upon the charcoal. Heated to a red heat it continues to glow for a long time without being further heated, and gives off dense white fumes. The fumes gradually crystallize and form, around the glowing metallic globule, a net-work of small crystals, which have a pearly lustre, and finally completely cover it; by lamp-light the globule of metal may be seen for some time, glowing within the mass by which it is entirely surrounded. This net-work consists of crystals of oxide of antimony, and melts if the flame be directed upon it. Metallic antimony, heated alone in the matrass, does not volatilize at the temperature at which glass melts. Heated to a red heat in an open glass tube, it burns slowly with a white fume, which deposits on the glass, and shows signs of crystallization. These fumes are mere oxide, and can be driven from one place to another, without leaving a trace behind. When, however, antimony is in combination with sulphur, besides the oxide of antimony, a portion of antimonious acid is formed, which can be recognized by its remaining as a white coating on the spot from which the oxide has been driven by the heat.

The *oxide of antimony* is easily fused, and sublimes in white fumes. As obtained by precipitation, washing and drying, it often has, before it begins to melt, the property of taking fire and burning like tinder; it then becomes infusible, and is converted into antimonious acid. On charcoal it is reduced to metallic antimony, and tinges the flame green.

*Antimonious acid* does not melt, but gives out a brilliant light, and diminishes in size in the interior flame, during which the coal becomes coated with white fumes, but it is not reduced, like the oxide, in this manner.

*Antimonic acid* becomes white after the first action of the heat, and is converted into antimonious acid. Antimonic acid containing water, changes at first from white to yellow, gives off water, and becomes again white on being ignited, losing a portion of its oxygen at the same time.

All these different degrees of oxidation behave in the same manner with the fluxes.

*Borax* dissolves antimonious acid in large quantities without losing its transparency. The glass gives out a yellow light when warm, but after cooling it is only very slightly tinged. When saturated, a part of the antimony begins to be volatilized in the metallic form, and covers the charcoal; when the glass is strongly heated in the reducing flame it becomes opaque and grey from the particles of reduced metal.

*Salt of phosphorus* dissolves it, and produces a clear, colorless glass. The bead may be tinged with a faint yellow color upon the platina wire, but the color soon disappears on cooling. If the bead contain iron, it has the same red color in the reducing flame which is produced by tungstic and titanous acids containing iron. Skilful blowing will reduce and volatilize the antimony, and cause the color to disappear. This takes place also on the addition of tin.

The oxides of antimony are dissolved by *soda* on the platina wire into a clear, colorless bead, which becomes white on cooling. On charcoal the antimony is reduced.

For medicinal and pharmaceutical purposes, it is often necessary to examine the oxide of antimony for arsenious acid. If the oxide of antimony be treated on charcoal with *soda*, it gives off the arsenical odor, even if the antimony does not contain a thousandth part of arsenic. Antimony also gives off an odor, but faint, and not resembling at all that produced by arsenic. When the proportion of arsenic is so small that it cannot be detected by the smell, it can easily be recognized by GÖBEL's method, by means of the formate of soda. The oxide is to be mixed with this salt, and the mixture heated in the

closed tube till it melts and becomes liquid. A combination of oxide of antimony and soda is formed, which melts, while the arsenic, together with a small portion of antimony, is reduced and sublimes. The tube must then be cut off close by the sublimate, so that this remains in the closed part of the tube; the sublimate can then be heated over the lamp, and if arsenic be present its smell will be distinctly perceived. If the tube be cut off so as to leave the sublimate in that part which is open at both ends, it burns so rapidly, on being heated, that its smell cannot be observed.

#### 18. TELLURIC ACID AND TELLUROUS ACID, OR OXIDE OF TELLURIUM.

Telluric acid, gently heated in a closed tube, gives off water and becomes dark yellow. More strongly heated, it becomes milk-white, and is converted into tellurous acid. A glowing match, held in the tube, shows a disengagement of oxygen. If the tube be heated to a low red heat, the tellurous acid fuses to a yellow liquid, which, on congealing, becomes colorless, crystalline, and opaque. Small globules generally remain transparent.

*Alone*, on platina foil, tellurous acid fuses, and emits fumes; on charcoal, it is fused and reduced with effervescence. The reduced metal may easily be mistaken for antimony or bismuth. I shall speak of the proper method of distinguishing these metals, under the head of bismuth.

With *borax* and *salt of phosphorus*, on platina wire, it gives a transparent, colorless glass, which is rendered grey and opaque, on charcoal, by particles of reduced and finely-divided metal.

With *soda*, tellurous acid gives, on platina wire, a transparent, colorless glass, which becomes white on cooling. On charcoal, it is reduced, and forms telluride of sodium, which sinks into the charcoal. If tellurous acid, soda, and finely-scraped charcoal be strongly heated in a closed tube, till fusion takes place, and then a few drops of boiling water be let fall into the tube, the water is soon tinged with a fine purple-red color, showing the presence of telluride of sodium.

#### 19. TANTALIC ACID.

*Alone*, it is unchanged.

*Borax* dissolves it to a clear, colorless glass, which is rendered opaque by the intermittent flame, and which, if a still larger quantity be added, on cooling, becomes enamel-white.



With *salt of phosphorus*, it dissolves easily and in large quantity, forming a colorless bead, which remains transparent on cooling.

It unites with *soda* with effervescence, and dissolves in small quantity, forming a transparent bead. A still larger addition does not fuse, and is not reduced.

Since tantalic acid strongly resembles the earths proper, it may easily be mistaken for them in blowpipe experimentation. Tantalac acid can, however, be distinguished by this, that its combination with the salt of phosphorus does not become opaque on cooling, not even if it be added in excess, which is the case with glucina, yttria, and zirconia. When a large excess of tantalic acid is added to the salt of phosphorus, it divides itself among the mass of the glass; this becomes, on being fused, opaque, but the undissolved matter does not become milky, but semi-transparent, like silica, from which, however, it is easily distinguished by its behavior with soda. It can be distinguished from alumina by its behavior with borax, and the solution of cobalt, which does not give a blue with the tantalic acid.

## 20. TITANIC ACID.

*Alone*, it remains unchanged.

It is easily dissolved by *borax* into a colorless glass, which, in the intermittent flame, becomes milk-white. If still more of the titanic acid be added, it becomes of itself white on cooling. If the glass be heated in the reducing flame, with a small quantity of the titanic acid it is first yellow, and afterwards, when the reduction is complete, the glass acquires a dark, amethystine color, which becomes very evident on cooling. The glass is transparent, and not unlike that produced by the oxide of manganese in the oxidating flame; it is, however, somewhat more blueish. If more titanic acid be added, and the bead be treated on the charcoal with a strong reducing flame, it becomes dark yellow, and assumes, on cooling, so dark a blue color, that it seems black and opaque. If afterwards heated in the intermittent flame, it becomes light blue, but opaque and enamel-like. The color is a more or less beautiful blue, and has different shades in different experiments. The cause of this is, that the glass contains titanic acid as well as oxide of titanium; the latter renders the glass dark blue, and the former, which contributes nothing to this color, produces the enamel-white color in the intermittent flame. When the white and the dark blue are mingled, a light blue is obtained, whose

shade depends entirely on the relative quantities of oxide and acid in the glass; so that, when it contains only a very small quantity of acid, it is black, and when, on the contrary, it contains very little oxide, it is rendered white by the intermittent flame.

The salt of *phosphorus* dissolves it, in the exterior flame, to a clear and colorless glass. In the reducing flame, it gives a glass which looks yellowish as long as it is hot; but, on cooling, it becomes red, and finally acquires a fine violet-blue color. If too much titanitic acid be used, the color is so deep that the bead becomes opaque, but it does not become enamel-like. The color can be driven off in the exterior flame. The reduction can be better performed on charcoal than on the platina wire, but requires, even on the charcoal, a strong and continuous heat, especially when titaniferous minerals, like sphene, are to be examined.

When the titanitic acid contains iron, or if iron be added to the glass colored by titanitic acid, the violet color of the oxide of titanium disappears, and the glass acquires, in the reducing flame, the same red color as from tungstic acid containing iron. If the quantity of these substances is very minute, the color is yellowish red, and does not make its appearance till the bead has cooled, and, in general, does not acquire its highest intensity till the glass is entirely cold. This reaction is so delicate, that, when the glass contains so little pure titanitic acid that its presence cannot be safely inferred from its color, if a small quantity of iron, most conveniently in the metallic form, be added, the reaction is most decided. The same shade of color in the bead is produced in the reducing flame, by tungstic acid containing iron, by antimonious acid containing iron, and by the oxide of nickel. It is, however, easy to decide which of these substances it is which is contaminated by iron. The antimonious acid can be easily driven off, after a strong heating, and the color of the iron remains. I have mentioned that tungstic acid containing iron gives, on the addition of tin, a green, or sometimes a blue, glass; when the ferriferous titanium glass is treated in the same way, the color due to the iron disappears, and the violet color of the titanium again appears. For this purpose, the color of the flux must not be too deep. If it should be, more flux must be added. It often happens that so small a quantity of ferriferous oxide of titanium colors the glass, that the titanium contained in it would alone hardly produce a visible reaction; in this case the tin destroys the reaction entirely, by completely removing

the color. Let the attempt then be made to prepare a glass of the salt of phosphorus, fully saturated with the substance to be examined, and let this be treated with the tin, by which means it not rarely happens that the peculiar color of the oxide of titanium may be recognized, especially when the glass is entirely cooled. The reaction produced by the oxide of nickel can be distinguished from the foregoing, in that it is strongest when the glass is hottest, and disappears almost entirely on cooling, and also in that the color is the same in the exterior as well as the interior flame; while, in the other cases, it disappears in a strong oxidating flame. The above-described reaction of iron upon the color of titanitic or tungstic acids does not take place with borax.

Titanic acid combines with *soda* with effervescence, and forms a clear, dark green glass, which is not absorbed by the charcoal, and which, on cooling, becomes grey or white. This glass has the property of crystallizing, exactly at the moment that it ceases to be ignited; and, in this operation, so much heat is developed, that the bead becomes again, of itself, white-hot. This property is common to all bodies which crystallize at a very high temperature, as, for instance, the phosphate of lead; I have, however, never had an opportunity to observe a substance where the heat was so intense and so lasting as in this. The proper proportion of the substances contributes much to the striking effect of this phenomenon. If more titanitic acid be used than the soda is able to dissolve, so that the undissolved portions swim in the glass, it never takes place; but, if soda be then gradually added, till exactly the proper proportion be reached which is required to dissolve the titanitic acid, the phenomenon is most strikingly successful. If still more soda be added, the crystallization diminishes till all is absorbed by the charcoal.

Titanic acid cannot be reduced on the charcoal by the aid of soda. In the experiments which I made, I used titanitic acid prepared from French rutile, according to LAUGIER's method, and obtained at each operation a few flat grains of a malleable, white, unmagnetic metal, which had the appearance of tin. I found, afterwards, that when the titanitic acid, precipitated from French rutile, was digested in hydrosulphate of ammonia, a trace of tin was dissolved by it, which remained behind after the evaporation of the liquid and the ignition of the dry residuum; this was easily reduced, and fused into a globule.

With the *cobalt solution*, the titanitic acid becomes black, or dark grey.

## 21. OXIDES OF URANIUM.

*Alone*, the oxide of uranium is reduced to the protoxide, and becomes black, but does not melt.

The oxide is dissolved with *borax* into a dark yellow glass, which becomes dirty green in the reducing flame. The yellow color can be restored upon the platina wire in the oxidating flame. On charcoal, this is very difficult. The green glass, at a certain degree of saturation, can be rendered black by the intermittent flame, and does not become afterwards either enamel-like or crystalline.

With the *salt of phosphorus*, on the platina wire, in the oxidating flame, it gives a transparent yellow glass, of which the color diminishes in intensity as it cools, and finally becomes straw-yellow, bordering on green. In the reducing flame, it gives a fine green bead, of which the color becomes still more beautiful as it cools. On charcoal, it is difficult to obtain any other than a green color, although the green is weaker in the oxidating flame.

*Soda* does not dissolve it. A very small quantity of soda gives signs of fusion. If still more be added, the mass becomes yellowish brown in the reducing flame, as an oxide is formed, which saturates the alkali, like an acid. By a still further addition, it can be carried so far that it becomes absorbed by the charcoal, but it is not reduced. Generally, traces of tin are found, if this metal be not removed from the oxide by hydrosulphuric acid or hydrosulphate of ammonia.

## 22. OXIDES OF CERIUM.

*Alone*, the protoxide is converted into a peroxide. This remains unchanged in the reducing flame.

*Borax* dissolves the oxide, in the exterior flame, to a fine red or dark yellow glass, of which the color diminishes as it cools, till it at length becomes yellow. It can be rendered enamel-white by the intermittent flame. If more of the oxide be added, the glass becomes of itself enamel-white and crystalline on cooling.

*Salt of phosphorus* dissolves the oxide into a fine red glass, which loses its color on cooling, and becomes transparent and colorless. The glass is colorless in the reducing flame, but there is never so large a quantity dissolved that it becomes opaque on cooling.

It is not dissolved by *soda*. The soda is absorbed by the

charcoal, and the protoxide of cerium remains behind, of a white or light grey color.

The reactions of the oxides of cerium resemble exceedingly those of the oxide of iron, especially when the oxide of cerium is combined with silica, which prevents the glass from becoming opaque with borax. They can be distinguished from each other by the unlike behavior of the protoxides with the fluxes; but, when both are found in combination with silica, as often happens, the presence of the oxide of cerium cannot be detected by the blowpipe.

### 23. OXIDE OF LANTANIUM.

The oxide of lanthanum behaves like the oxide of cerium, with this difference, that, dissolved in the fluxes, it gives less highly colored beads, which, in the exterior flame, have no color, if the oxide of lanthanum be pure.

### 24. OXIDE OF DIDYMIUM.

*Alone*, it does not fuse, but loses its brown color in an intense reducing flame, and becomes grey.

It dissolves in *borax* and *salt of phosphorus*, and gives in the outer flame a transparent, dark, amethystine-colored glass, similar to that obtained from titanate acid in the reducing flame.

With *soda*, it behaves like the oxide of cerium.

### 25. OXIDE OF MANGANESE.

*Alone*, it does not melt, but, at a high temperature, becomes brown.

It is easily dissolved by *borax*, in the oxidating flame, to a clear, amethystine-colored glass, which loses its color in the reducing flame. If the quantity of manganese be considerable, the bead must be thrown so as to fall upon a cold body, the moment the blowing is discontinued, otherwise it recovers its color if slowly cooled. If the quantity of oxide be sufficient, the glass is at length so deeply colored that it appears black; but it is still transparent in thin threads.

It is easily dissolved by *the salt of phosphorus* into a transparent glass, which is colorless in the reducing flame, and amethystine in the oxidating flame; the color is never so deep that it loses its transparency. As long as the glass continues

melted, either upon the charcoal or on the platina wire, it continues to boil, and gives off gas. This process ceases in the reducing flame, but commences again in the oxidating flame. The cause seems to be this: the glass bead becomes oxidized upon the surface, and, as the oxidized portion is carried into the interior of the mass by the revolutions of the bead, oxygen is disengaged by the phosphoric acid, and the salt of the oxide is changed to a salt of the protoxide. Thus it happens that the salt of phosphorus only acquires the amethystine color to a certain extent, since only a certain amount of the oxide can be taken up by the glass. In general, the borax glass can be easier oxidized than reduced; and the glass of the salt of phosphorus, on the other hand, is obtained in a perfect state of reduction, but can only be imperfectly oxidized. When the glass of the salt of phosphorus contains so little oxide of manganese that the color is no longer visible, it can be rendered evident, if the melted bead be touched with a crystal of saltpetre, in the manner described before in treating of the reagents; the bead foams, and the foam takes an amethystine or a rose-red color during the cooling, according as the substance contains more or less manganese.

The oxide of manganese is dissolved, in very small quantity, by *soda*, on the platina wire. The glass is transparent green, and, on cooling, it congeals, and becomes blueish green. This succeeds best on platina foil. The solution of the oxide of manganese in the soda flows about the undissolved portion, so that the color of the salt is distinctly visible after cooling. A thousandth part of manganese in the substance tested colors the soda distinctly green, and in this way the smallest trace of manganese may be detected.

Manganese cannot be reduced on the charcoal with soda; if it contain the slightest trace of iron, however, that can be reduced, and can be separated in the usual way.

## 26. OXIDE OF ZINC.

*Alone*, it turns yellow when heated, which can be seen by daylight, but not by candle-light. The white color returns on cooling. It does not melt, but gives out a brilliant light when strongly heated, and gradually disappears in the reducing flame, while a white crust is deposited upon the coal.

It is easily dissolved by *borax* into a clear glass, which is rendered milk-white by the intermittent flame; and, if a larger quantity be added, it becomes enamel-white on cooling.

In the reducing flame the metal volatilizes, and the coal is covered with a white deposit around the assay.

With the *salt of phosphorus* it behaves as with borax, is however reduced, and easily volatilized.

It is not dissolved by *soda*; but treated with soda on the charcoal, it becomes reduced, and deposits upon the coal; with a strong heat the peculiar flame of burning zinc may even be observed. This reaction furnishes the best means of detecting zinc, and the presence of this metal in the minerals which contain it, as, for instance in Gahnite, is known at once by the incrustation which deposits on the charcoal, when the mineral is treated with soda.

## 27. OXIDE OF CADMIUM.

*Alone*, on platina, in the outer flame, it remains unchanged. On charcoal it disappears in a short time, and deposits upon the charcoal a red or dark yellow powder. This behavior of the oxide of cadmium is so striking, that if, for instance, carbonate of zinc, which contains one or two per cent. of carbonate of cadmium, be exposed for an instant to the reducing flame, a yellow or dark yellow ring of the oxide of cadmium will be deposited at a short distance from the assay, which can best be observed after the charcoal has been allowed to cool. It is formed long before the zinc begins to be reduced, and if the zinc begins to be deposited, it is a proof that the operation has been too long continued. If this yellow deposit be not observed before the zinc begins to incrust the charcoal, it is proof that the zinc contains no cadmium.

It is dissolved by *borax*, in large quantity, and gives a yellowish transparent glass, of which the color mostly disappears on cooling. When the glass is nearly saturated, it becomes milk-white in the intermittent flame, and when fully saturated, it becomes, of itself, on congealing, enamel-white. On charcoal, the borax glass containing cadmium boils incessantly, cadmium is reduced and volatilized, and the coal is covered by a dark yellow deposit of oxide of cadmium.

It is dissolved in large quantity by the *salt of phosphorus*, into a transparent glass, which when saturated becomes milk-white on cooling.

It is not dissolved by *soda* upon the platina wire. On charcoal it is reduced, volatilizes, and deposits a dark yellow ring of the oxide of cadmium.

## 28. OXIDE OF IRON.

*Alone*, it remains unchanged in the exterior flame, but in the interior flame it becomes black and magnetic.

It is dissolved by *borax* in the oxidating flame into a dark red glass, which on cooling grows lighter, becomes at last yellowish and even colorless. If a larger portion be added, it becomes, when fused, opaque, and has, on cooling, a dirty dark yellow color. In the reducing flame, it becomes bottle-green, and when the reduction is carried as far as possible, a clear blue-green color is obtained, exactly like that obtained by dissolving iron in diluted sulphuric acid. The addition of tin hastens the reduction to the state of protoxide. The bottle-green color properly belongs to the proto-peroxide; it is often so dark that it appears black. As long as the glass contains only the peroxide of iron it remains transparent while fused, but as soon as it is exposed to the reducing flame, and the proto-peroxide begins to be formed, it becomes opaque, and continues so till the operation is carried so far that only the protoxide remains, when it becomes again transparent. The green color of the protoxide is very beautiful, as long as the glass is warm; but it diminishes on cooling, and disappears if the quantity of iron is trifling.

It is dissolved by the *salt of phosphorus*, with the same phenomena of color, as by *borax*, but the color decreases still more on cooling. By adding tin it can be caused to disappear almost entirely. A glass containing a large proportion of iron, acquires, on being treated with tin, a faint blueish green color; sometimes the bead acquires, at the moment of cooling, a greyish pearly color, which, however, disappears on its being reheated.

It is not dissolved by *soda*, but is absorbed by the charcoal, is easily reduced, and gives, when washed, a grey magnetic powder.

## 29. OXIDE OF COBALT.

*Alone*, it remains unchanged.

It is easily dissolved by *borax*, and gives a clear blue bead, which does not become opaque in the intermittent flame. A small quantity of the oxide colors the glass deeply, and if a larger quantity be added, the glass becomes so dark blue, that it appears black.

It is dissolved by *salt of phosphorus*, with the same facility



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and with the same color. The cobalt color inclines to violet, when seen by artificial light, but by daylight it is a clear blue. When the salt of phosphorus bead has a feeble blue color by daylight, it appears by candle-light of a faint rose-red.

It is dissolved by *soda*, on the platina wire, in small quantity; the melted mass is, when viewed by transmitted light, faint red, and becomes, on cooling, grey. It melts with soda on platina foil, the dissolved portion runs off at the sides, and the platina acquires around the undissolved portion a thin dark red coating.

The oxide of cobalt is dissolved in a far larger proportion by the *basic carbonate of potash*, the salt does not flow about as much, and the mass becomes black, without any shade of red.

On charcoal, the oxide of cobalt is easily reduced, with the alkali, in the interior flame, even if so little be employed that it does not become absorbed by the charcoal; but it cannot be fused. After washing away the soda and the coal, there remains a grey magnetic metallic powder, which takes a metallic lustre, when burnished.

## 30. OXIDE OF NICKEL.

*Alone*, it undergoes no change.

It is easily dissolved by *borax* into a dark yellow or reddish glass, which becomes light yellow, or nearly colorless, on cooling. A larger quantity of the oxide produces a glass which, while fused, is opaque and dark brown; but, on cooling, it acquires a clear, deep red color, like that of ferriferous tungstic acid in the salt of phosphorus. The addition of saltpetre or carbonate of potash changes the color to a blue or deep purple, by which it is distinguished from the oxide of iron, of which the color with borax resembles that of the oxide of nickel. This color is destroyed in the reducing flame, and the glass acquires a greyish appearance from the particles of finely divided, metallic nickel, which, on continuing the operation, collect together without fusing. If the oxide of nickel contains cobalt, as often happens, its color makes its appearance; if it contain at the same time arsenic, it melts to a bead.

If a small quantity of nickel occurs with a large proportion of cobalt, it is no easy matter to discover the presence of the former. PLATTNER gives the following method for that purpose. The borax glass is to be almost saturated with the assay, and the glass is afterwards to be melted with four or five

centigrammes of fine gold in a strong reducing flame. All the oxide of nickel with a portion of the oxide of cobalt is thus reduced, and a regulus of nickel, cobalt and gold is obtained. This must be flattened out with the hammer, cleared of the powdered glass, and again melted with fresh borax in the exterior flame. The cobalt is first oxidized, and dissolves in the flux. A blue glass is obtained, which, when it acquires a deep color, must be separated from the regulus. If the blue is not so deep, but that it can be seen whether the color changes to green, the blowing is to be continued till the glass begins to turn green. The cobalt is then oxidized, and the gold contains only nickel. The regulus is again purified by hammering it out, and then kept for some time in fusion with fresh borax, in the external flame. The nickel is gradually oxidized, and imparts to the borax glass the brown color, characteristic of the oxide of nickel. (The gold is afterwards purified by cupellation.)

It is dissolved by the *salt of phosphorus* with the same colors as with borax, but the color disappears almost entirely on cooling, and is, moreover, the same, both in the reducing and the oxidating flame, by which it is distinguished from iron, which, however, it much resembles in its behavior. An addition of tin produces, at first, no change, but afterwards the nickel is precipitated and the color vanishes.

If the substance contains nickel, it will now be appreciable; but the blue glass is not clear, and, in general, the oxide of cobalt cannot be so easily detected in this way, as by the borax glass.

The oxide of nickel is not dissolved by *soda*. If a large quantity of soda be employed, it is absorbed by the charcoal, is easily reduced, and gives, after washing, small, white, brilliant, metallic particles, which are attracted by the magnet with almost more strength than iron itself. With a small proportion of soda, the mass remains on the surface of the charcoal, but the nickel is reduced, and can be obtained by dissolving the soda. This pure nickel cannot be fused with the blowpipe. Nickel containing a trace of arsenic does not fuse with soda, but if a little borax be added, it melts to a bead, which is malleable, and can be flattened out; generally, however, it cracks a little at the edges, and is strongly attracted by the magnet.

### 31. BISMUTH AND ITS OXIDE.

*Alone*, the oxide of bismuth is melted on platina foil to a dark brown mass, which becomes pale yellow on cooling.

is reduced by too strong a heat, and perforates the platina. On charcoal, it is at once reduced to one or more metallic grains.

It is dissolved by *borax*, without becoming colored, in the exterior flame. In the interior flame, it is reduced, and gives a greyish glass, clouded by particles of finely divided bismuth.

It is dissolved by *salt of phosphorus*; the glass is yellowish brown when hot, and becomes colorless, but not quite transparent, on cooling. In the reducing flame, especially if tin be added, a glass is obtained which is transparent and colorless when hot, but it becomes grey and opaque on cooling, like that of the protoxide of copper, excepting the color, which in the latter is red. This circumstance would seem to indicate a lower degree of oxidation than is known by preparation in the humid way.

The facility with which bismuth can be reduced, causes it to become an object of blowpipe investigation, generally, in the metallic state. It is then important to be able to distinguish it from tellurium and antimony, with which it is easily confounded.

a. *In the closed tube*, neither bismuth nor antimony are sublimed at any temperature which the glass permits. Tellurium, on the contrary, first gives off a small quantity of fumes (caused by the oxygen of the atmosphere in the tube), and afterwards a grey sublimate of metallic tellurium is obtained.

b. *In the open tube*, antimony gives off white fumes, which coat the glass internally, and which can be driven from one spot to another by the application of heat, so that nothing is left upon the glass. The metallic bead is surrounded by a considerable quantity of the fused oxide.

*Tellurium* rises in dense clouds, and deposits on the glass a white powder, which melts to clear colorless drops, when heated; a small portion volatilizes, but the larger part only changes its place in such a manner, that the drops, if of large size, are mechanically driven from one place to another. If the coating be thin, it seems to be driven entirely away by the heat, but the magnifying glass shows that the powdery substance has collected in small globules. The metallic bead becomes enveloped with a fused, clear and almost colorless oxide, which, when cooled, by forming a thicker coating, becomes white, opaque and foliated. If the heat be strong, and the air have slight access, a part of the tellurium is sublimed in the metallic state, as a grey powder.

*Bismuth* gives off scarcely any fumes, if not combined with sulphur; the metal surrounds itself with the fused oxide, of a

dark brown color, which becomes pale yellow on cooling. It attacks glass strongly, and dissolves its substance.

c. On *charcoal*, all three of these metals are volatilized, if the blowing be long continued, and deposit a ring around upon the charcoal. That of antimony is quite white, bismuth and tellurium have a red or dark-yellow edge. If the reducing flame be directed upon this deposit, it disappears, and the flame is colored beautifully and strongly green by the tellurium, weak greenish-blue by the antimony, and it acquires no color whatever from the bismuth.

I must here remark, that the odor of decayed horse-radish, which is often ascribed to tellurium, is not a characteristic of this metal, but belongs to selenium, which accompanies many ores of tellurium.

### 32. OXIDE OF TIN.

*Alone*, the protoxide, the pure as well as the hydrate, burns like tinder when heated, and is converted into a peroxide. The peroxide is not changed or fused, but in a strong and long-continued reducing flame, pure oxide of tin may be entirely reduced, without any addition, to metallic tin. This, however, requires practice in the use of the blowpipe.

The oxide of tin is slowly and in small quantity dissolved by borax. It gives a transparent glass, which remains transparent on cooling. It cannot be rendered enamel-white by the intermittent flame, but if the saturated glass, after becoming quite cold, be exposed again for some time to the exterior flame, and heated to a dull red-heat, it becomes opaque, loses its spherical form, and becomes indistinctly crystalline. The color of the glass is not changed in the reducing flame. By a long-continued exposure to the reducing flame, small globules of reduced tin are made to appear.

By the *salt of phosphorus*, the oxide of tin is slowly dissolved in minute quantity to a clear colorless glass. If oxide of iron be added, it loses its property of coloring the glass. It is to be observed, that only a certain proportion of the oxide of tin has the property of destroying the color of a certain quantity of the oxide of iron, and that the excess of the latter colors the glass, as if no oxide of tin were present. The presence of arsenic renders the glass opaque.

With *soda* on the platina wire, it combines with effervescence, forming a swollen unfused mass, which cannot be dissolved by the addition of more soda. On charcoal it is easily reduced to a globule of metallic tin. Certain varieties

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of oxide of tin, especially if tantaliferous, are difficultly reduced by the use of soda only, so that the tin in such substances might escape observation ; but if a small quantity of borax be added, the reduction is easily effected.

Tin occurs, in nature, very often as an accidental ingredient, mixed in very minute quantity with minerals containing tantalum, titanium and uranium, and perhaps others, where its presence is not even suspected in an analysis in the humid way ; but if they be treated with soda before the reducing flame, especially after the iron has been removed from them, metallic tin is always obtained, even when it does not constitute over  $\frac{1}{2}$  per cent. of the substance. If the proportion of iron be not very large, its reduction can be prevented by the addition of borax to the soda.

### 33. OXIDE OF LEAD.

*Alone*, minium appears black, as long as it remains hot, and changes, at a low red heat, into the yellow oxide. The yellow oxide melts to fine dark yellow glass, which is reduced upon the charcoal, with effervescence, to a grain of metallic lead.

It dissolves with *borax* on the platina wire to a transparent glass, which is yellow, if saturated, as long as it remains hot, but becomes colorless after cooling. The assay cannot be brought into a bead upon charcoal, but it spreads out upon the coal ; the lead is reduced, and flows towards the edges.

It is easily dissolved by the *salt of phosphorus* to a transparent glass. When saturated, it appears yellow when fused ; it becomes enamel-white on cooling. It is not reduced by the interior flame, unless an excess of the oxide of lead be present.

The oxide of lead is readily dissolved by *soda* on the platina wire to a transparent glass, which, on cooling, becomes yellow and opaque. The lead is instantly reduced on charcoal.

### 34. OXIDE OF COPPER.

*Alone*, treated in the oxidating flame, the oxide of copper melts to a black bead, which soon spreads out upon the charcoal, and becomes reduced upon the under side. In the reducing flame, the oxide is reduced and acquires a metallic lustre, at a temperature below the melting point of copper ; but as soon as the blowing is discontinued, the surface of the metal

is instantly oxidized and becomes black or brown.\* In a stronger heat, it melts to a globule of copper.

The oxide of copper is easily dissolved by *borax*. The glass is of a fine green color, but at the moment in which the glass congeals, it acquires a cinnabar-red color, and becomes opaque. If the oxide of copper be impure, the glass is often dark brown, and does not acquire an enamel-like appearance, as in the intermittent flame. If the proportion of copper be large, a part of the metal is reduced to a melted globule, which can be obtained by breaking the glass.

It is dissolved by *salt of phosphorus* with the same color as with borax. If the quantity of copper be small, the glass, treated in the reducing flame, sometimes becomes ruby-red; this happens generally at the moment of congelation. It is, however, almost always red, opaque and enamel-like. If the amount of copper be so small that the reducing flame cannot produce the reaction of the oxide of copper, a little tin must be added to the borax or salt of phosphorus glass; if the bead be then heated, the glass, which before was colorless, becomes red and opaque on cooling. If the heat be kept up too long, the copper is precipitated in the metallic form, especially from the salt of phosphorus, and the reaction is prevented.

In analyses of minerals containing lead, if the lead be separated by means of hydrosulphuric acid, when converted into an oxide it still contains a portion of copper, which is not distinguished by the color. This, however, can be detected in the following manner, according to PLATTNER. A cavity is made in the charcoal, in which boracic acid is melted; the reduced bead of lead is then laid on the edge of the acid, and gently heated in the oxidating flame. The lead oxidizes, and is taken up by the acid. When, at last, only a very small quantity remains, it is treated with the salt of phosphorus, when the reaction of the copper can be observed, either with or without the aid of tin.

\* GAHN, who had large copper-works near Fahlun, which he managed with the utmost care, found that ores taken from different parts of the mine required different methods of treatment, in order that too large a quantity of the metal might not be lost in the slag. In order to discover by some short process, whether the proportion of copper in the slag was increasing, he tested them with the blowpipe in the following way. A thin and broad fragment of the slag, of which the surface had been ground flat, was heated, in the first place, in the oxidating flame, in order to drive off the sulphur, and then in the reducing flame, so that the flame was spread out upon the already roasted surface. If the slag contained copper, metallic points and spots having the color of copper made their appearance, by the number and size of which the percentage of copper was estimated. Rarely was a slag found entirely free from copper, but the eye soon learned to decide what was the common percentage, and what too large an amount.

The oxide of copper is dissolved by *soda* on the platina wire to a transparent green glass, which becomes colorless and opaque on cooling. On charcoal the mass is absorbed, and the metal reduced. There is no better method of detecting minute quantities of copper than by reduction, in those cases in which the copper is not combined with other metals which are liable to be reduced at the same time, and thus to mask its reaction. Should such be the case, borax must be used with tin. When copper and iron occur together, both metals are obtained together in separate particles by the process of reduction, and can be distinguished by the color, and by the aid of the magnet.

### 35. MERCURY.

The combinations of mercury are all volatile, so that no reaction can be obtained with the fluxes. Mercurial substances are best examined by mixing them with metallic tin, iron-filings or oxide of lead, or, what is still better, soda, and then placing them in a glass tube closed at one end, and heating them to ignition. The mercury is reduced, and collects in the cold part of the tube in the form of a grey coating, which, when stirred, collects in small metallic globules.

### 36. OXIDE OF SILVER.

*Alone*, it is instantly reduced.

*Borax* partly dissolves and partly reduces it. Heated in the oxidating flame, the glass acquires, after cooling, a milk-white or opalescent appearance, according to the quantity of silver dissolved. The same result takes place, if silver in the metallic form be added. In the reducing flame, it becomes grey from particles of metallic silver disseminated through the mass.

With the *salt of phosphorus*, the oxide and the metal give, in the oxidating flame, a yellowish glass, which acquires an opaline tint from a greater proportion of silver. Seen by transmitted light, it appears yellow; by candle-light, it has a reddish appearance. It becomes grey in the reducing flame, like the glass of borax.

The remaining precious metals, gold, platina, iridium, rhodium, and palladium, give no reaction with the fluxes, and are not oxidized. To this rule, however, rhodium and palladium are an exception, since they are oxidized and dissolved by the bicarbonate of potash, if fused with it. The operation

must be performed in the closed glass tube over the spirit-lamp, since the sulphuric acid escapes too quickly from the platina foil. Platina and iridium are not attacked by this flux. The only thing which can be done with these metals is to treat them with the fluxes, to see whether any oxidizable metals can be detected in combination with them. In the same manner, they can be melted with pure lead, and cupelled, to determine, from the color of the cupel, whether they contain foreign metals. Of the above-mentioned metals, only gold can be obtained in a coherent globule. The others remain, after cupellation, in the form of a grey, infusible, porous mass, which acquires a metallic lustre under the burnisher; and, if it be platina or palladium, it is malleable.

## B. COMBINATIONS BETWEEN COMBUSTIBLE BODIES.

### 1. SULPHURETS OF METALS.

The sulphurets are recognized by the smell of the sulphurous acid which they disengage on being roasted on charcoal, or in the glass tube. If a metallic combination contains so little sulphur that it cannot be detected by the smell on being roasted, a bead of soda and silica must be melted, and to this the substance to be tested is to be added, when the glass acquires a red or yellow color, immediately or after cooling, according to the proportion of sulphur present. If other metals should tinge the glass, so that the color produced by the sulphur cannot be seen, the assay must be fused with soda in the reducing flame, and then laid, after being moistened with water, upon a piece of silver foil, which is immediately discolored by the sulphur. The assay can also be roasted in the open tube, in the open end of which a piece of Brazil-wood paper is placed; this will be bleached by a quantity of sulphur too small to be perceived by the smell. This precaution is to be taken especially in the treatment of antimony ores, where the smell of sulphur can with difficulty be perceived, since the vapor of antimony has itself an acid smell.

In testing sulphurets, the object generally is, to discover with what metal the sulphur is combined; for this purpose, as much of the sulphur as possible must be burnt off. To effect this, thin fragments of the assay are best selected, since these are most easily penetrated by the air; round and thick masses must be avoided. For the same reason, the heat must at first be gently applied, in order that the assay may not melt



into a mass. If it should be fused, it is better to choose another fragment. After the process of roasting has been carried to a certain point, certain metals are no longer liable to fuse, and the heat can be increased in order to hasten the roasting, and to decompose the sulphate which generally forms during the process. The roasting is best performed upon charcoal. If performed on platina, it must be remembered that the platina is liable to be attacked by the metal, and both the assay and the support may be destroyed. If charcoal be not used, a sheet of mica, silver, or fire-clay can be employed.

When the roasting is finished, the action of the fluxes can be observed. The reduction with soda requires that the sulphur should have been completely driven off, since, otherwise, sulphurets may be formed which cannot be recognized, or which may be dissolved and washed away, so that nothing is left in the mortar in which the operation is performed.

The volatile sulphurets must be roasted in a tube open at both ends, with proper precaution that the sulphuret be not volatilized at the same time. The sublimed oxide is then to be collected and examined.

## 2. SELENIURETS.

These can be most readily detected by the smell which they disengage when heated in the external flame. It is best recognized by holding the assay, while still hot, under the nose. It then smells strongly and disagreeably of decayed horse-radish; and this smell is so characteristic, that by it the slightest trace of selenium may be detected.

Heated with a glass of silica and soda, the reaction is the same as that of the sulphurets, but the color is more easily destroyed than that of sulphur by long continued heating; and, if it be fused with soda upon charcoal, the metal is reduced, and seleniuret of sodium is obtained, which, when moistened with water, and laid upon silver, leaves the same stain as the sulphuret of sodium or hepar.

By roasting in an open glass tube, it is often easy to obtain selenium in the metallic form. By inclining the tube at a certain angle, the draught of air can be so modified that the other substances are oxidized, while the selenium sublimes of a red color. If a seleniuret occurs, mixed with a sulphuret, the selenium is sublimed alone, and the sulphur is volatilized in the form of sulphurous acid. Some of the Swedish specimens of galena contain a minute proportion of selenium, which

may be thus detected. If the selenium is accompanied by tellurium, the oxide of tellurium is first sublimed, while the selenium is afterwards deposited nearer the heated spot. Sulphuret of arsenic is often sublimed like selenium, but, in this case, the assay gives the smell of arsenic, and not of selenium.

### 3. ARSENIURETS.

Arsenic is detected by the smell which it gives off when the assay is heated, in which operation it must be remembered that it is not the arsenious acid, but the metallic arsenic in a gaseous form, which has the odor of garlic. If the proportion of arsenic be considerable, the assay fumes strongly, and the arsenical smell is perceived at a considerable distance. If the quantity be less, the assay must be strongly heated in the reducing flame, and held directly under the nose; if, however, the proportion of arsenic be very minute, its smell is hardly to be detected without heating it in the reducing flame with soda. The smell is so delicate a test for the presence of this metal, that if, for instance, a small piece of paper colored in the usual manner with smalt be burned, and the ashes collected and strongly heated in the reducing flame, the smell of the minute proportion of arsenic contained in the smalt will be distinctly perceived.

If an arseniuret is to be roasted, the operation is best begun in a tube, since in this way the greater part of the arsenical vapors condense in the tube, as a white crystalline sublimate, and are not mixed with the air of the room. In this way, the smell of the sulphurous acid can be best perceived, as the gas deposits its arsenic upon the tube. When the greater part of the arsenic has been separated in this way, the roasting is finished upon the charcoal; and, for this purpose, both flames must be alternately used, since a part of the arsenic combines with the metallic oxides, as an acid; this portion must therefore be restored to the metallic state, and again roasted in the oxidating flame. It is still more necessary to drive off the arsenic than the sulphur, especially in cases of reduction, since the reducible metals are much more difficultly recognized if contaminated with arsenic.

In roasting substances containing arsenic, the operator should not unnecessarily expose himself to its fumes, which are always injurious; though I must confess that I have often had my room full of arsenical vapors, without experiencing any injurious effect. I found, to my astonishment, the air

around the silver-furnaces near Freiberg smelling most strongly of arsenic, without perceiving any signs of its injurious effect upon the workmen, who are exposed to this atmosphere almost every day.

#### 4. ANTIMONIURETS.

These give off, when roasted in the open tube, antimoniaccal fumes, which, however, differ in character according to the nature of the various metals with which the antimony is mixed. If they are easily oxidized, antimonious acid is formed; and, in this case, the sublimate is infusible. Antimony is driven off from copper and silver, and an oxide is formed, which deposits upon the glass as a volatile sublimate. The fumes which rise from the tube have a distinctly acid smell, which seems to belong to the oxide, or to the antimonious acid.

#### 5. TELLURETS.

Roasted in the glass tube, they produce in the upper part of the tube the same deposit as pure tellurium (see bismuth). The fumes which issue from the tube have a peculiar acid smell, like the vapor of antimony. The deposit of the oxide of tellurium is distinguished from that of arsenious acid, in that the first is not crystalline and can be fused, while, on the contrary, the latter is crystalline, and volatilizes without fusing.

Tellurets, mingled with soda and finely-scraped charcoal, and heated in the closed tube, as described under the head of telluric acid, produce telluret of sodium, which can be dissolved out of the tube, after allowing it to cool, with a few drops of water which has been boiled for some time; it can then be recognized by its purple color. Since, however, the tellurets not unfrequently contain sulphur, a combination of telluret of sodium with sulphuret of sodium is obtained, which, by its yellow color, mingled with the red of the telluret of sodium, sometimes produces an orange-red.

#### 6. CARBURETS.

Those carburets of which the composition corresponds with that of the sulphurets and antimonurets, that is to say, those from which salts of the carbonates can be formed, do not occur in the mineral kingdom. They can be artificially produced by

the dry distillation of certain vegetable matters, or by heating the cyanurets of certain metals in closed vessels. These have then the combustibility of charcoal, can be set on fire, and burn like tinder, leaving behind the metallic oxide; this property depends principally upon their porous texture.

The only test for carbon in the dry way is, that it gradually consumes, without fumes or smell; and that, when mixed with saltpetre, and heated in the platina spoon, or on platina foil, it detonates, and forms a carbonate of the alkali.

### C. REACTION OF ACIDS WHEN IN COMBINATION WITH SALTS.

What has been already said of the phenomena presented by the metallic oxides, considered each one by itself, can be applied to the detection of the nature of the base of a saline combination, especially if it be a metallic oxide. It now remains to give rules by which the acid, or the electro-negative element of a combination, may be detected. To determine whether the substance to be tested contains a mineral acid, it is to be melted, according to the method proposed by SMITHSON, with soda, on platina foil. The melted mass is then to be dissolved in water, of which a clear drop is then to be let fall upon glass, saturated with acetic acid, and tested by a solution of the acetate of lead. All the mineral acids, except the nitric, give precipitates.

#### 1. SULPHURIC ACID

Is detected in the salts of the sulphates, by adding an extremely minute quantity of the salt to a bead of silica and soda fused together, or by mixing it with soda before melting it with silica. The latter is most easily effected, but the former gives a surer result. The sulphuric acid is reduced, and sulphuret of sodium is formed, by which the glass is colored dark brown, or becomes colorless while fused; but after cooling it acquires a red or dark yellow color, according to the quantity operated on. The presence of sulphuric acid is also detected by melting the salt with soda in the reducing flame, and then taking it from the charcoal and laying it moistened upon a piece of silver foil, by which it is blackened, or stained deep yellow.

## 2. NITRIC ACID.

The salts of the *nitrates* are recognized by their deflagration with charcoal when they are fusible. Those which do not melt are to be heated to ignition, after being perfectly dried, in a glass tube closed at one end, when the tube is soon filled with a dark yellow vapor of nitrous acid.

## 3. CHLORIDES.

I made many researches to discover a test for chlorine in the dry way. A remark of BERGMAN, that chloride of copper tinges the flame green, which is not caused by any salt of copper in combination with a mineral acid, led me to make the following experiment, which succeeded beyond all expectation. Oxide of copper is dissolved in the salt of phosphorus, till a dark green bead is obtained. To this the substance to be tested for chlorine is to be added, and the blowing continued. If the assay contains chlorine, the bead becomes surrounded by a beautiful blue flame, inclining to purple, which continues as long as any chlorine remains. No one of the acids which occur in the mineral kingdom produces anything similar, and those whose copper salts alone color the blowpipe flame, do not, when treated with the salt of phosphorus. Thus, for instance, the blowpipe flame is colored intensely green by the earthy mineral in which the blue carbonate of copper occurs, at Chessy in France; but if the salt of phosphorus be added to it, if previously saturated by the oxide of copper, the flame does not exhibit the slightest trace of color. There is still another method of detecting chlorine, which is thus performed. Sulphate of iron or oxide of copper is placed on a bright sheet of silver, a drop of water let fall upon it, and the metallic chloride laid upon it, when the silver after a while acquires a deep bronze color.

## 4. BROMIDES

Give with salt of phosphorus and oxide of copper, as well as with the sulphate of copper on silver foil, the same reaction as the chlorides; but the blue color of the flame inclines rather to green than purple, especially on the edges. To distinguish with certainty the bromides from the chlorides, the substance must be fused with bisulphate of potash (both anhydrous) in a small glass matrass with a long neck. Bromine

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and sulphurous acid gas are disengaged, and the matrass is filled with a yellow vapor, which can be distinctly recognized by its smell, although mixed with sulphurous acid. The color of the gas cannot well be seen by candle-light, for which reason this operation must be performed by daylight.

### 5. IODIDES.

Tested in the same way as the chlorides, tinge the flame with a beautiful dark green color. It must be observed, however, that the salt of phosphorus at the commencement of fusion often throws out small jets of flame tinged of a greenish hue by the combustion of ammonia, and that in a strong reducing flame it emits a greenish light; this cannot, however, be confused with the brilliant green flame which is caused by an iodide. Iodides fused with the bisulphate of potash in a glass matrass, give off a violet colored vapor, iodine being sublimed at the same time that sulphurous acid is disengaged.

### 6. FLUORIDES.

Since fluor has been detected in so many minerals in which its presence was formerly not even suspected, as, for instance, in wavellite, hornblende, and mica, it is of importance to be able to detect its presence by means of the blowpipe. This is not so easy in those cases where it forms an essential constituent of the mineral, as, for instance, in fluor spar, topaz, cryolite, &c., since the fluoric acid is not so easily driven off by the heat from these minerals, as from those in which it exists as merely an accidental ingredient, as, for instance, in mica and hornblende, in which the fluor is driven off by the change in the relative arrangement of the particles which ensues on ignition, in the form of fluo-silicic acid gas.

In the first place, the assay is to be mixed with salt of phosphorus, previously fused, and heated at the extremity of an open glass tube, so that a part of it is carried by the force of the current of the flame into the tube. In this way aqueous fluoric acid is formed, which gradually fills the tube, and which can be recognized by its peculiar odor, as also from the circumstance that the glass is attacked by it on the inside, and loses its polish, especially at those spots where moisture is deposited. If Brazil-wood paper be held at the orifice in the current of acid gas, it will be changed to yellow.\* SMITHSON

\* According to BONSENDORFF's researches, several acids, as, for instance, fluo-

performs this operation in this way : he fastens a piece of platina foil to the lower end of the tube, with a metallic wire, so that it forms a sort of canal before the glass tube. In this open canal, the assay is to be laid and heated, so that the product of the operation is driven into the glass tube. At the highest temperature to which the assay can be raised, according to his statement, the fluoric acid can be driven off from the topaz and fluor spar, without the assistance of the salt of phosphorus. SMITHSON also changes the arrangement, by attaching the tube by a metallic wire to a small cork, and fastening the assay with clay to the end of a platina wire opposite the lower open end of the tube, which wire is also fastened to the cork, by which the whole can be held in the hand, and turned so that the flame can be directed into the tube. If the finely pulverized assay be fused in a glass tube closed at one end, with four times its weight of bisulphate of potash, till sulphuric acid begins to be disengaged, the tube is more or less coated internally with silicic acid, which deposits from the fluo-silicic acid gas. The tube is then to be cut off above the fused mass, rinsed with water, and dried, when the reaction is distinctly seen.

When, on the other hand, fluoric acid is contained in minute quantity in a mineral, in which it is combined with weaker bases and water, the assay need only be heated in a glass tube closed at one end, in the open end of which a piece of moistened Brazil-wood paper is inserted. In general fluoric acid containing silica is driven off by the heat, and not far from the assay a ring of silica deposits in the tube, and the extremity of the Brazil-wood paper becomes yellow ; this reaction indicates that the volatilized acid is fluoric acid. In this manner the presence of fluoric acid can be detected in, for instance, a mica, which contains no more than  $\frac{1}{2}$  per cent. of its weight of that acid.

#### 7. PHOSPHORIC ACID SALTS.

The unexpected discovery of phosphoric acid in wavellite and lazulite, has shown the necessity of a reagent for this acid, especially since, as it is precipitated with the earths, it easily escapes the notice of the chemist. Its known behavior in

ric, phosphoric, and oxalic acids, have the property of coloring Brazil-wood paper straw-yellow, which is not effected by sulphuric, nitric, arsenic, and boracic acids. Therefore, in order to detect a combination of fluor, if it be moistened with chlorohydric acid in a watch glass, and the Brazil-wood paper be applied to it, after a short interval the reaction of the fluoric acid is rendered evident.

combination with the oxide of lead, induced me to attempt to discover some method of detecting its presence by the help of lead or the oxide of lead, which, however, did not succeed, except in the case of the phosphate of copper, unless I had beforehand combined the phosphoric acid with the oxide of lead in the moist way, an operation quite out of the sphere of blowpipe experimentation. After many ineffectual attempts, I at last hit upon the following plan, which answers the purpose excellently. The assay is dissolved in boracic acid, and when the mass is entirely fused, a piece of fine iron wire rather longer than the diameter of the bead is stuck through it, and the whole heated strongly in the reducing flame. The iron becomes oxidized at the expense of the phosphoric acid, by which borate of the protoxide of iron and phosphuret of iron are formed. The latter fuses at a high temperature, and the assay, which at first spreads itself over the wire, acquires its spherical form again, as soon as the phosphuret of iron fuses. As the bead cools, a sudden flash of light is generally seen in it, which is caused by the crystallization of the phosphuret of iron. The glass bead is then taken from the charcoal, wrapped in paper, and broken upon the anvil by a light blow of the hammer, when the phosphuret of iron appears as a round metallic grain, which adheres to the point of the magnetized knife, breaks under the hammer, and when broken has the color of iron. According to the proportion of iron it contains, it is more or less brittle, and the grain can often be partially flattened out, or struck a pretty heavy blow without breaking. If the assay contained no phosphoric acid, the wire comes out with its original shape and polished surface, being only burnt at the ends which projected from the bead. As small a proportion as four or five per cent. cannot be detected in this way, since it would fuse so small a quantity of iron that no result could be obtained which could be safely relied on.

As a matter of course, before the assay is examined according to this method for phosphoric acid, it must first be ascertained that no other substance is present which might be reduced by the iron and melted with it to a bead, as, for instance, sulphuric acid, arsenic acid, or such metallic oxides as are reduced by iron, since in such a case their bases would be obtained in combination with the iron.

### 8. SALTS OF THE CARBONATES.

The salts of the carbonates cannot be so easily detected by the use of the blowpipe, that the usual test in the humid



way by applying a drop of hydrochloric or nitric acid could be dispensed with.

### 9. BORACIC ACID.

For the detection of boracic acid in the salts of the borates, TURNER has given the following process. A quantity of finely pulverized fluor-spar is mixed with  $4\frac{1}{2}$  parts of bisulphate of potash and 1 part of the assay, and made up with water into a stiff paste, which is taken upon the platina wire, and, after being dried, heated just within the point of the blue flame; as soon as the mass is melted, a pure green color tinges the flame for a moment, and then disappears and is not repeated, and must, therefore, be observed at the moment of fusion. The theory is this; fluoboric acid is formed and disengaged, coloring the flame at the moment that it escapes.

### 10. HYDRATES.

Hydrates, or the combinations of water with oxidized bodies, are easily recognized, if the assay be heated in a small matrass, when the least trace of water is condensed in the neck of the matrass. Few substances are so free from hygroscopic moisture, that they do not give a trace of water when treated in this way.

### 11. SILICATES.

Silicates are decomposed by the salt of phosphorus, the silica is set free, and the bases combine with the free acid of the salt of phosphorus. If a small quantity of this flux be used, it often happens that the silica swells up at the moment that the substance is decomposed, and absorbs the liquid mass. If more flux be added, a bead can be obtained in which the swollen, semi-transparent mass of silica swims. This is better seen while the glass is in fusion, than after it has been allowed to cool. In a large proportion of silicates, it sometimes happens, that the bead, though transparent when fused, becomes opalescent on cooling. This is not the case with pure silica. If the assay contains only a trace of silica, this is generally entirely dissolved in the flux.

Every substance of an earthy or mineral nature, which melts with soda with effervescence into a transparent glass which remains transparent on cooling, is either silica, or a silicate in which the oxygen of the silica is generally at least double the

quantity of that of the base. The glass, which is a combination of soda and silica, has the power of dissolving the base, which the soda has set free from its combination with the silica. If, on the contrary, the substance contains a smaller proportion of silica, so that, for instance, the oxygen of the silica is equal in quantity to that of the base, the silicate is entirely decomposed, and a glass formed, but the quantity is not sufficient to dissolve the liberated base, into whose pores the glass is absorbed. Here a circumstance occurs which seems paradoxical, namely, that a substance can dissolve with a minute portion of soda and form a transparent glass, which, if more soda be added, becomes opaque and infusible. This happens generally in those fusible silicates, whose bases, although by themselves infusible, form a glass with soda. A small proportion of soda separates a portion of the infusible bases, but they still remain dissolved. The more soda is added, the larger the quantity of the base which is liberated, and it congeals at last into a swollen mass.

This relation between the phenomena which result from different proportions of silica undergoes no exception, although different bases behave in different ways. Since the silicates are generally double salts, and the bases are often united in different proportions, it often happens that two bases, which in a certain reciprocal relation to each other easily unite with soda, when otherwise combined are with great difficulty melted to a glass with it. If, for instance, the bases are  $C+3A$ , a glass can be obtained from the silicate, as well as from the bi- or tri-silicate. If, however, the bases are  $C+2A$ , the silicate forms no glass with soda. If the bases are  $C+M$ , the silicate is with difficulty fused to a glass; if  $C+2M$ , a liquid glass of the bi-silicate is obtained. If the bases are  $C+f$ , or  $C+mg$ , vitrification takes place most readily. Since in a great number of the most common silicates the crystalline form can be deduced from the proportion of silica which they contain, their fusibility with soda is a good method, in certain cases, of estimating, approximatively, the relative quantities of the bases.

## 12. SELENIC, ARSENIC, MOLYBDIC, TUNGSTIC, CHROMIC, TITANIC, AND TANTALIC ACIDS.

The salts of these acids are detected by the methods which have been before described; namely, selenic and arsenic acids by their smell in the reducing flame, as well as the seleniurets and arseniurets; the others by the reaction produced by their acids, in the manner which has been described in speaking separately of each of them.



## PART II.

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### BEHAVIOR OF MINERALS BEFORE THE BLOWPIPE.



## PART II.

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### BEHAVIOR OF MINERALS BEFORE THE BLOWPIPE.

I SHALL, in the following pages, describe the behavior of minerals before the blowpipe, observing the order of the electro-chemical system; according to which, I shall commence with the most electro-positive substances, and describe each compound substance under the head of its most electro-negative element. This arrangement is not a matter of consequence in a work like this, where the place of each mineral can be readily found by referring to the index; but, as a certain order must be followed, that ought to be preferred which, in a mineralogical point of view, offers the greatest advantages. I shall also add to each mineral the formula representing its composition, as far as such may have been determined, according to the generally received atomic weights.

#### NATIVE ELECTRO-POSITIVE METALS.

These are generally so easily recognized by their external characters, that they rarely become the objects of investigation before the blowpipe. Should they require to be examined in this way, they must first be oxidized, in order to be able to test them with the fluxes in their oxidized state.

The following may occasionally require examination:—

a. *Native palladium*, from Brazil.\* Carefully heated on platina foil over the spirit-lamp to a low red heat, it becomes tinged with blue, which color disappears at a full red heat.

*Alone*, on charcoal, it is infusible and unchanged. With sulphur, it fuses in the reducing flame. In the oxidating flame,

\* This experiment was performed with unhammered palladium, which was reduced from the oxide. As far as my knowledge goes, Dr. WOLLASTON is the only person who has had the opportunity of investigating native palladium.

*Telluret of lead*,  $\text{Pb Te}$  (mechanically mixed with  $\text{Pb S}$  and  $\text{Au Te}^3$ ), *Foliated tellurium* (Blättererz), from Nagyag.

Alone, on charcoal, it fumes, and leaves a yellow deposit upon the charcoal. The deposit disappears, tinging the inner flame blue, and not green, and leaves, after long-continued blowing, a grain of gold, which, at the moment of passing to a solid state, becomes again red hot. The grain is malleable.

In the glass tube, it fumes, smells perceptibly of sulphurous acid, but not at all of horse-radish, and gives a white sublimate, which is, however, grey directly over the assay. The sublimate which is deposited directly over the assay does not melt like the oxide of tellurium; it changes its appearance, and forms a grey semi-fused coating on the glass, without any perceptible fused globules. If such an examination should be made when the presence of tellurium was not previously suspected, this sublimate might be mistaken for antimonious acid, but is not so snow-white as this acid, which also does not become grey and partially fuse when heated. This is occasioned by the tellurate of the oxide of lead. At a considerable distance from the assay, it has the fusibility and reaction of the oxide of tellurium. The metallic globule remaining in the glass is surrounded by a dark oxidized mass, which looks like the oxide of bismuth; but the color remains after cooling, and does not become much lighter. The test with boracic acid, recommended by PLATTNER, and given under the head of telluret of bismuth, gives, in this case also, a result which can be depended on as accurate.

*Telluret of silver*, from Savodinskj,  $\text{Ag Te}$ . In the open tube, it fuses, without fuming or sensibly changing. On charcoal, it gives off fumes on being raised to a white heat. The edge of the flame is tinged blue, but there is no deposit upon the coal. The bead, as it congeals, becomes covered with silver-white crystalline ramifications, which are probably metallic silver from which the tellurium has been volatilized. These ramifications become still more extended on further heating, and they finally change into small globules, which sometimes shoot out upon fine threads. At length, the whole bead acquires a homogeneous silvery surface. The grain is then malleable, but breaks at the edges.

With borax and salt of phosphorus, in the oxidating flame, a transparent yellowish glass is obtained. In the reducing flame the glass is colorless, but becomes grey and opaque on cooling. If the metallic globule be removed, all the metal contained in the borax glass may be soon expelled; with greater difficulty, however, out of the salt of phosphorus, which,

with a larger proportion of metal, becomes opaque and white on cooling. After long continued heating, it becomes opalescent, but only on congealing.

Soda combines with the tellurium, boils and is absorbed by the charcoal, while the silver remains behind. It is wholly freed of its tellurium only by repeated fusion with soda.

With soda and charcoal-powder in the matrass, telluret of sodium is obtained, which forms a fine red solution.

*White tellurium*,  $\text{AgTe} + 3\text{PbTe} + 2\text{AuTe}^3$ , behaves like the foregoing, except that on cupellation on charcoal oxide of tellurium is deposited, and afterwards it gives yellow fumes of lead, and leaves behind a grain of silver exceedingly rich in gold.

*Graphic tellurium*, (Schrifterz) from Nagyag.

Alone, it melts on charcoal to a dark grey metallic bead, deposits white fumes upon the charcoal, which disappear with a green or bluish-green light when the flame is directed upon it. After long blowing a light yellow metallic grain remains behind, which at the instant of solidifying becomes, of itself, white hot. The brilliant metallic globule is malleable.

In an open tube a white fume deposits, which, near the assay, is grey (from sublimed tellurium). The sublimate fuses into clear and transparent drops, when the flame is directed upon it; it smells acid, but without any trace of the smell of horse-radish.

#### ANTIMONY AND THE ANTIMONIURETS.

*Native antimony*, Sb, from Sala, behaves like pure antimony, and is dissipated in fumes, leaving no residuum.

*Antimonial silver*, (Spiesglanzsilber,)  $\text{Ag}^2\text{Sb}$ , and (Silber-spiesglanz,)  $\text{Ag}^3\text{Sb}$ .

Alone, it fuses readily on charcoal to a grey, brittle, metallic globule, and fumes like antimony, but not so strongly; the globule acquires, after a certain proportion of the antimony has been driven off, a dull, white, and strongly crystalline appearance, and gives out a sudden light at the moment of solidifying. After losing still more antimony, it becomes, on cooling, smooth and polished on the surface, like glass, and is at that instant strongly ignited. Finally, after long ignition, nothing but silver remains behind. The fumes of antimony are deposited on the charcoal, and this is sometimes tinged with red, in the direction of the flame, probably from the sulphur contained in the assay, which forms crocus of antimony.

Heated in the tube, a great quantity of the oxide of antimony is given off, and the remaining globule becomes surrounded by a ring of a dark yellow glass.



*Antimonial nickel*,  $\text{Ni}^2 \text{Sb}$ , from Andreasberg in the Harz.

In the open tube it gives off white fumes without fusing. The sublimate, if collected and treated with formate of soda, (see oxide of antimony, page 60,) gives a very trifling ring, which volatilizes with the smell of arsenic. The roasted assay is greyish-green and infusible.

On charcoal, the assay melts at a high temperature, and continues to fume like antimony for a few moments, yet without covering itself with crystallized oxide of antimony. The fumes smell strongly of arsenic. The addition of soda brings out the arsenical smell still more strongly. The soda is absorbed by the charcoal, but does not give any reaction of liver of antimony on metallic silver.

With borax and salt of phosphorus, glass beads are obtained, which are colored by the oxide of nickel.

#### ARSENIC AND ARSENIURETS.

*Native arsenic*, As, from Saxony, when heated, smells of garlic. In the matrass, it sublimes, and leaves behind a small globule of metallic silver. The sublimate is metallic arsenic.

*Observation.* Many varieties of native arsenic, as they are commonly called in various collections, are either biarseniurets, or mixtures of biarseniurets with arsenic, as, for instance, the columnar arsenic, from Schneeberg, and the testaceous cobalt from Saxony, and other biarseniurets of cobalt.

*Copper nickel*, (Kupfernickel,)  $\text{Ni}^2 \text{As}$ , from Schneeberg.

In the matrass, it gives off no fumes, and partially fuses as the glass begins to grow soft. It gives a deposit of white arsenic, which is formed by the air in the matrass.

On charcoal it fuses, fumes, and smells of arsenic, leaving a brittle, white, metallic globule.

In the open tube it is easily roasted, gives off a large quantity of white arsenic, and leaves behind a yellowish-green substance, which, when roasted on the charcoal and fused with soda and borax, gives a tolerably malleable, magnetic, metallic globule.

After roasting, it behaves with the fluxes like the oxide of nickel, and after the reduction generally tinges the glass of a blue color, by which the presence of cobalt is recognized.

*Arsenical nickel*, (Arseniknickel,)  $\text{Ni As}$ , behaves like the foregoing, with this difference, that in the matrass arsenic is sublimed, and leaves a copper-colored residuum of copper nickel, (Kupfernickel.)

*Arsenical cobalt*,  $\text{Co As}$ , sometimes  $\text{Co}^2\text{As}^3$ , (Speiskobalt,) from Riegelsdorf, Schneeberg and Bieber.

Alone, in the open tube, gives off readily arsenious acid.

In the matrass, some kinds give metallic arsenic, others do not. On charcoal they fume and emit the odor of arsenic, giving a fused white bead, which, even after long fusion with borax and soda, remains brittle, and tinges the fluxes with the peculiar color of cobalt.

*Columnar arsenic*, from Schneeberg, (Stängliches Arsenik,) *Testaceous cobalt*, (Scherbenkobalt) from Saxony, give off, in the matrass, no arsenic, or at most only a trace.

In the open tube a white sublimate is obtained, partly of arsenious acid, and partly of metallic arsenic, while a greyish-brown infusible mass remains behind. Thoroughly roasted, it dissolves readily in the fluxes.

They are taken up by borax, and give it a cobalt color, without producing any other reaction. They are dissolved by salt of phosphorus, giving a cobalt color to the bead; but the columnar arsenic gives also evident marks of the reaction of the oxide of nickel, which passes into a cobalt-blue, as soon as the nickel is precipitated by tin.

*Arsenical antimony*, (Arsenikspiesglanz, Antimoine testacé de Poullaouen.)

Alone, in the matrass, it gives off at first a large quantity of metallic arsenic, afterwards it begins to melt, and at length ceases to sublime. If the metallic globule be taken out and heated to ignition on charcoal, it does not burn with the same phenomena as antimony, but the fumes smell strongly of arsenic. The fumes crystallize gradually around the metal, and the crystals are whiter, and in larger laminæ than those of pure antimony. If the ignition be continued, it volatilizes entirely.

## CARBON.

*Graphite* is little changed by the action of the blowpipe flame. By long-continued blowing, it decreases in size and leaves an ash, which has the reaction of the oxide of iron, and sometimes of titanous acid. If graphite be rubbed upon fire-clay and then heated, the streak becomes gradually red, from the oxide of iron left behind.

Graphite, (Kohlenblende,) from Barreros in Minas Geraes in Brazil, often leaves no red streak, and is therefore pure carbon.

*Lignite, mineral charcoal*, when heated, burns like tinder, and leaves a white ash, which is not alkaline.

*Anthracite* gives off water in the matrass, but no empyreumatic oil. It burns in the oxidating flame without fusing, and leaves a small quantity of ashes.

#### SELENIUM AND SELENIURETS.

*Seleniuret of lead*,  $\text{Pb Se}$ , from Tilkerode in the Harz Mts.

Alone in the matrass it decrepitates, often violently, but otherwise remains unchanged.

On charcoal it fumes, smells strongly of selenium, deposits on the coal a red, yellow and white incrustation, and tinges the flame blue. It does not fuse, but becomes rounded, and gradually volatilizes, smelling constantly of selenium. It leaves behind a very trifling quantity of black slag, which gives with borax indications of iron, and in the reducing flame traces of copper.

Roasted in the open tube, it gives off at first a little selenium, but undergoes but a very trifling change. The sublimate, at the greatest distance from the assay, is red, nearer to it, it is of a steel-grey color.

Cupelled with lead on a bone-ash cupel, it often leaves a trace of silver, and sometimes gold.

It is gradually dissolved by soda, and is absorbed by the charcoal; the lead is reduced, and can be separated by washing.

*Seleniuret of lead and cobalt*,  $\text{Co Se}^2 + 6 \text{ Pb Se}$ , from Tilkerode, behaves like the seleniuret of lead, but the remaining slag gives a blue glass with the fluxes.

*Seleniuret of copper*,  $\text{Cu}^2 \text{ Se}$ , from Skrickerum.

Alone, on charcoal, it fuses into a grey and slightly malleable bead, at the same time smelling strongly of selenium.

In the tube, selenium sublimes in the form of a red powder, and also selenious acid, which crystallizes before the selenium; the crystals are volatilized by a very gentle heat. After long-continued roasting, during which the assay gives off the odor of selenium, if it be treated with soda, a grain of copper is obtained.

*Seleniuret of copper and lead*, (Selenkupferblei und Selenbleikupfer,) from Tilkerode and Glasbachsgrunde. It varies in composition:  $\text{Cu Se} + 4 \text{ Pb Se}$ ,  $\text{Cu Se} + 2 \text{ Pb Se}$ , and  $\text{Cu Se} + \text{Pb Se}$ .

The first of these behaves like seleniuret of lead, but fuses slightly on the surface. After long-continued roasting it leaves a black slag, which, when fused with borax, gives the reaction of copper, and if soda be added, a globule of copper is sepa-

rated in the flux. The last named ore fuses readily, spreads on the charcoal and forms a grey mass, having a metallic lustre, which, after a thorough roasting, gives with borax and soda a grain of copper.

*Seleniuret of copper and silver*,  $\text{Cu}^2\text{Se} + \text{Ag Se}$ , *Eucairite* from Skrickerum.

Alone, it fuses, smells strongly of selenium, and gives a grey, soft, but not a brittle, metallic globule. Cupelled, after being mixed with lead, it gives a grain of silver, and smells strongly of selenium during the whole operation.

In the open tube it behaves like the seleniuret of copper.

With the fluxes it gives a decided reaction of copper.

*Seleniuret of mercury and lead*,  $\text{Pb Se}$  mixed with  $\text{Hg Se}$ , from Mädesprung.

Alone in the matrass it gives a grey, crystalline sublimate of seleniuret of mercury, and sometimes, before this, a few globules of pure mercury. Heated with soda in the matrass, it gives only mercury. Its behavior is, in general, like that of the seleniuret of lead.

#### SULPHUR AND THE SULPHURETS.

*Native sulphur*, S and (')\*, is easily recognized by its smell when burning. In the matrass it sublimes; it is distinguished from the sulphuret of arsenic, by this, that if burnt in an open tube nothing condenses on the surface of the tube above the place of combustion.

*Sulphuret of manganese*, Mn, (Manganz) from Nagyag.

Alone in the matrass it undergoes no change. Heated in the open tube, it is gradually and slowly roasted, without subliming. The roasted surface acquires a greyish-green color; it remains for a long time unchanged internally. It can be fused with a strong reducing flame, on the edges to a brown slag, when roasted to a certain extent. Thoroughly roasted, it behaves with the fluxes like pure oxide of manganese.

It is very slowly dissolved by borax; the glass acquires, on cooling, a faint yellowish color, as long as any part of the assay remains undissolved. This color seems to be similar to that which sulphur imparts to a glass of soda and silica. When the

\* I shall make use here of the symbol for the sulphurets which I proposed in the 1st Part of the 4th edition of my Elements of Chemistry. It consists in placing a comma for each atom of sulphur, over the symbol of the radical; for instance,  $\text{FeS} = \text{Fe},$ . The convenience of this method of notation will be clearly seen farther on.

assay is fully dissolved, and the deoxidizing action has ceased, the color of the oxide of manganese is perceived.

It is dissolved by the salt of phosphorus with strong effervescence, and the escape of a large quantity of gas, which continues for a short time, after heat ceases to be applied. If the bead be placed almost in contact with the flame, slight detonations are heard, caused by the combustible gases, which are evolved and set on fire. If a larger bead which remains hot for a longer time be taken, the detonations last longer, and near the end a large bubble of gas is given off, which burns with a feeble green light; it is easy to perceive by the peculiar, garlic smell of the boiling globule, that the gas is a sulphuret of phosphorus, which is produced by the oxidation of the metallic manganese at the expense of the phosphoric acid, while the sulphur combines with the phosphorus and escapes. The glass exhibits, in this case, a curious play of colors; it is clear and colorless so long as it remains fused, but acquires the same yellow color as the borax glass on cooling. At first, when only a small portion of the assay has been decomposed, it becomes, on cooling, of a light yellow color, but the color gradually increases in depth, and at the moment of congelation a substance is separated from it, which causes the bead to appear black. Examined with the microscope, small black particles are seen scattered through the dark yellow glass, and on cooling it transmits a bluish light.\* When all the sulphuret of manganese is decomposed, and the effervescence has entirely ceased, the glass is perfectly transparent and colorless, and it acquires, in the oxidizing flame, a beautiful, clear amethystine color.

It is imperfectly dissolved by soda. The hepatic mass is absorbed by the charcoal, and a grey sintered slag remains on the surface.

*Sulphuret of zinc, Zn, Blende.*

Alone, it sometimes decrepitates strongly; it can be ignited without any particular change; it does not fuse but becomes rounded on its thinnest edges, in the strongest heat which can be produced; it smells feebly of sulphurous acid, and is not easily roasted.

In the open tube it does not give off fumes, and undergoes little change. On charcoal it deposits a coating of zinc, when strongly heated in the external flame.

\* The cause of this play of colors cannot be sulphur. Is the sulphuret of manganese soluble in the salt of phosphorus, or is there a lower degree of oxidation than the protoxide, which, like the lowest oxides of copper and bismuth, is soluble in the melting acid, and which, on cooling, is separated?

It is scarcely acted on by soda, but the zinc is reduced, so that, if the heat is sufficient, the flame of burning zinc is perceived, and flowers of zinc are deposited upon the coal.

*Sulphuret of iron.* a. *Magnetic iron pyrites.*  $\text{Fe} + 5\text{Fe}$ , (Magnetkies) from Utö.

Alone in the matrass it undergoes no change. In the open tube it gives off sulphurous acid, but no traces of a sublimate. On charcoal it reddens in the exterior flame, and is converted into peroxide of iron by roasting. In the inner flame, it melts with a strong heat into a globule, which continues red hot for an instant after being taken from the flame. After cooling, it is covered with a rough, black mass. If the globule be broken, the fracture is crystalline, with a yellowish color and metallic lustre.

b. *Bisulphuret of iron*,  $\text{Fe}$ , *Iron pyrites*, (Schwefelkies.)

Alone in the matrass it throws out a smell of hydrosulphuric acid gas, and gives off sulphur. After a strong heating, a reddish sublimate is obtained, which is less volatile than sulphur, and the quantity of which varies in different specimens. This sublimate looks like sulphuret of arsenic. The sulphuret of iron, when thoroughly roasted, is metallic, porous, attractable by the magnet, and behaves like the magnetic pyrites.

On charcoal it reacts like the magnetic pyrites.

*Sulphuret of cobalt*,  $\text{Co}$ , (Kobaltkies,) with occasional admixture of  $\text{Fe}$  and  $\text{Cu}$ , from Bastnäs near Riddarhyttan and from Müsen.

Alone in the matrass it does not give off fumes, as one would expect from the formula  $\text{C}^2 \text{S}^3$ . It does not decrepitate. In the open tube it gives off sulphurous acid, accompanied by a white sublimate in trifling quantity. This sublimate consists of small drops, as is seen if it be examined by the microscope. It is concentrated sulphuric acid. If the tube be dusty, it becomes black from the decomposition of the dust. The sulphuric acid is given off at the commencement of the operation, and is not visibly increased in quantity by its continuance. No trace of arsenic can be perceived. It is roasted upon charcoal, and afterwards fuses to a grey, metallic globule, which cannot easily be freed from sulphur.

With the fluxes, the reaction of the cobalt overpowers that of the iron and copper, so that the latter cannot be recognized, but after the grey fused bead has been several times remelted in the oxidating flame, the cobalt is taken up, and the copper becomes concentrated, so that, finally, if the glass be exposed to the reducing flame after being saturated with the salt of

phosphorus; on cooling, the red color of the protoxide of copper appears, although shaded with the blue of the cobalt.

*Sulphuret of nickel*,  $\text{Ni}$ , (Haarkies.)

In the open tube it smells of sulphuric acid, bleaches Brazil-wood paper, and leaves a dark mass, unaltered in form.

Strongly heated on charcoal it gives a malleable, magnetic sinter, which is nickel.

After being roasted, it behaves with the fluxes like the oxide of nickel.

It gives, before being roasted, a hepatic color with a glass of soda and silica.

*Sulphuret and antimoniuiret of nickel*,  $\text{Ni} + \text{Ni Sb}$ , (Nickel-spiesglanzerz.) (The antimony is partially replaced by arsenic. The nickel sometimes contains traces of cobalt.)

In the open tube it gives off strong fumes of antimony, smells slightly of sulphurous acid, and bleaches Brazil-wood paper held in the tube.

In the matrass it gives off a trifling white sublimate, which seems to be formed at the expense of the air in the matrass.

On charcoal it fuses and gives off dense fumes. The arsenical smell is not easily recognized, but can sometimes be perceived in a slight degree. The metallic bead, however long it may be roasted, still remains fusible and brittle. With soda it does not emit the odor, or fumes, of arsenic, nor does it sink into the charcoal, but forms a black, liquid mass, which remains on the surface, and collects into a bead. This flux produces with the glass the color of hepar. The metallic globule, melted with the fluxes, gives no other reaction than that of the cobalt.

*Sulphuret of copper*,  $\text{Cu}$ , *Vitreous copper*, (Kupferglas.)

Alone on charcoal it smells of sulphurous acid, fuses easily in the external flame, and boils, throwing off melted globules. In the internal flame, it becomes covered with a crust, and no longer fuses. This can be repeated several times. No copper is separated, as long as any sulphur remains, and it appears from this, that sulphur and copper can be fused together in any proportion.

In the open tube it gives off sulphurous acid, and is roasted, but does not sublime. The roasted assay gives a globule of metallic copper with soda or borax.

*Sulphuret of iron and copper*. a. *Copper pyrites*,  $\text{Cu}^{\text{III}}\text{Fe}$ , (Kupferkies,) and b. *Variiegated copper*,  $\text{Cu}^{\text{III}}\text{Fe}^2$ , (Buntkupfererz.) (Sometimes mixed, in various proportions, with  $\text{Cu}$ ,  $\text{Fe}$ , or with  $\text{Fe}^{\text{III}}$ .)

Alone, on the charcoal, it becomes darkened by the first action of the flame, and turns black, but changes to red on cooling. It fuses more readily than the sulphuret of copper to a globule, which, after being heated for some time, is attractable by the magnet. It is brittle, and its fracture is greyish-red. Exposed for some time to the oxidating flame, and afterwards treated with borax, it gives a globule of copper. In the open tube it gives a strong smell of sulphurous acid, but no sublimate. In the matrass there is no sublimation of sulphur.

After being roasted, it gives with the fluxes the reaction of a mixture of the oxides of iron and copper. Treated with soda, iron and copper are obtained separately, after burning off all the sulphur.

*Sulphuret of lead, Pb, Galena, (Bleiglanz.)*

Alone, on charcoal, it does not fuse till all the sulphur has been driven off, when globules of lead make their appearance on the surface, and a button of lead is at last obtained. If this be cupelled, it can be determined whether the assay contains silver. The color of the bone-ash cupel shows after the operation is finished, whether the lead was pure or not. If pure, it has a clear pale\*yellow color; copper stains it of a greenish hue, iron, black or brown, &c. The bone-ash cupel can be used, either for roasting or for cupelling.

In the tube, sulphuret of lead gives off sulphur and a white sublimate of the sulphate of lead, which becomes, in a strong heat, grey near the assay. The sublimate can be fused by a strong heat; it congeals immediately, and does not volatilize.

*Remark 1.* Since the sulphuret of lead is one of the principal ores from which silver is obtained, the assaying of it for that metal is of great importance, and, since this can be done by cupellation with the blowpipe, HARKORT endeavored to use this instrument for quantitative analyses, so that it would be possible in twenty minutes to arrive at a pretty accurate knowledge of the quantity of silver contained in the assay. Although such a technical use of the blowpipe does not properly come within the limits of this division of the work, I will, notwithstanding, briefly describe his method of operating.\*

A larger quantity of the assay than can be used in the cupellation is to be taken, pulverized and well mixed, so that an average of the whole may be obtained. A decigramme (which

\* "Die Probirkunst mit dem Löthrohre" by EDWARD HARKORT. Part 1st, Assaying of Silver. Freiberg, 1827. PLATTNER has, since that time, carried still farther the art of making quantitative assays with the blowpipe, not only for silver, but for some other metals. "Die Probirkunst mit dem Löthrohre" by C. F. PLATTNER. Leipzig, 1836, pp. 251 to 350.



is called the standard cwt.) is weighed on a delicate balance, or by means of NICHOLSON'S hydrometer, which is sunk in alcohol to make it more susceptible. The weighed powder is then placed in a small ivory capsule, and mixed with pulverized borax glass, in proportion to the quantity of foreign matters contained in the assay, and decomposed by from 3 to 8 times its weight of pure finely granulated lead. The lead is not weighed, but measured in a graduated cylinder, in which one degree marks a space sufficient to contain a decigramme of lead. The mass is then well mingled, and placed in a small cone of post paper, which has been previously soaked in a solution of soda and dried. The cone is closed at both ends, after filling it with the assay, and then laid in a cavity in the charcoal and heated. The paper and the soda hold the mass together, till the borax glass has become sufficiently soft to prevent any particles from being scattered and lost. The mass soon melts, and the borax takes up the slag, while the lead containing the silver forms a coherent regulus. It is easily seen whether the slag is too large in quantity to be separated from the lead, in this case, it must be remelted with more borax. The cupels are made of bone-ashes, in an iron mould, which resembles the steel anvil described on page 26, and which is provided with a steel handle, and has three cavities in which the bone-ashes are placed to form the cupels.\* The cupellation requires two operations. The first time, it is carried so far, that two thirds of the lead is oxidized, which must be done with care, to allow as little oxide as possible to be absorbed by the cupel, which is then to be broken away on the side, till the globule is exposed, so that it can be taken out from the surrounding oxide with the forceps. It is then placed upon a fresh cupel, and heated till it is oxidized and absorbed by the bone-ashes. The globule of silver which remains is too small to be weighed, and HARKORT proposed to measure it; for this purpose he prepared a scale of ivory, on which is cut a right-angled triangle, whose base is a millimetre in length, its height 157.5 millimetres; it is divided into 50 equal spaces, forming 50 triangles, which decrease regularly in height. The grain of silver, is placed on this triangle, and slid along till its surface is seen, the eye being held directly over it, to exactly touch the sides of the triangle, when the number of loths of silver contained in a hundred weight of ore can be read off on the nearest divi-

\* In repeating HARKORT'S experiments, I used, instead of the iron mould, one of pumice stone, which, apart from its liability to be broken, answered the purpose very well, and is not liable to become so hot that it cannot be held in the hand.

sion. This scale cannot be made from calculation, since the grain of silver is not spherical, but gradually becomes flatter as it enlarges. It is, therefore, constructed from experiments made first in the humid way, and afterwards repeated with the blowpipe, so that each division of the scale corresponding to the diameter of the silver globule is marked with the number determined by experimentation in the large way. Thus, after several points of the scale were fixed, the rest was interpolated in the same ratio. Analyses performed in the large way agreed, not exactly, but sufficiently near for practical purposes, with those performed with the blowpipe according to this method.

It was properly only for operations of this kind, that HARKORT invented the blowing machine described on page 13, for relieving the muscles of the cheeks and lips.

*Remark 2.* The sulphuret of lead from Fahlun and from the copper mines of Ätvidaberg, smells of selenium when roasted on charcoal, and if the operation be performed in the tube, a red sublimate of selenium is obtained, which, although not large in quantity, is sufficiently evident. For this purpose the roasting must be slowly performed, and continued for a long time, since the selenium does not separate till near the end of the operation. A red ring is then seen to be formed about an inch from the assay, and the smell of selenium is recognizable in the upper end of the tube. The selenium is collected by heating the space between the assay and the ring, so that the selenium which is deposited there is driven towards the ring. If the amount of selenium is small, the ring is hardly to be discerned by transmitted light, but it becomes evident when held against a dark ground. If there is arsenic in the assay, sulphuret of arsenic may easily give rise to mistakes.

*Sulphuret of bismuth, a*, from Greger's Klack, Bispsberg, Bi, or Bi + 2S.

Alone, in the tube, it gives off sulphurous acid and a white sublimate, and boils violently on being heated to ignition, which soon ceases, and oxide of bismuth is deposited around the globule, as is the case with pure bismuth.

On charcoal it fuses and boils, throwing out small red-hot globules for a short time. After the bismuth is driven off, a small slag remains, which is dissolved by the salt of phosphorus with the characteristic color of iron.

*b.* From Riddarhyttan, *Bi*.

In the tube it gives off, at first, sublimed sulphur, then a small quantity of a sublimate, which resembles the fumes of

tellurium in its property of fusing on being heated, but the globules become brown and cloudy-yellow on cooling, while those of tellurium, on the contrary, are transparent and colorless, when the deposit is not too thick. After a part of the sulphur has been burned away, it begins to boil and spirt like the foregoing variety, and leaves a regulus of bismuth, which, when cupelled, leaves behind a clear orange-yellow stain on the cupel.

*Remark.* It seems to follow from these experiments, that the native bismuth found fifty years ago on the Greger's Klack in Bispberg, is really sulphuret of bismuth, but containing a smaller proportion of sulphur than that of Riddarhyttan, which seems to be brought by roasting to have the same composition as the preceding.

*Sulphuret of copper and bismuth*,  $\text{Cu}^{\text{I}}\text{Bi}^{\text{III}}$ , (Kupferwismuthertz,) from Wittichen in Fürstenberg.

In the open tube it gives off sulphur and a white sublimate. The assay then boils, but less violently than the sulphuret of bismuth.

On charcoal it emits burning globules, at first, and coats the coal with a deposit of bismuth, but cannot be fused on account of the quantity of quartz which it contains. If it be treated with soda, after being roasted, it gives a globule of metallic copper of considerable size.

*Needle ore*,  $\text{Cu}^{\text{I}}\text{Bi}^{\text{III}} + 2\text{Pb}^{\text{II}}\text{Bi}^{\text{III}}$ , (Nadelierz,) from Katharinenburg.

Alone it fuses and fumes, coats the charcoal with a white deposit, which is slightly yellow on its edge, and gives a metallic globule, resembling bismuth. The fumes are reduced by the interior flame, and do not become colored.

In the open tube it gives off white fumes, which can be fused into liquid globules, some of which are white after cooling, and others volatile. The air issuing from the tube smells of sulphurous acid. The globule of bismuth becomes covered with a black fused oxide, which after cooling is transparent and greenish-yellow. The globule gives with the fluxes the reaction of copper, though indistinctly. After long heating a globule of copper remains, which, when cupelled, leaves behind an exceedingly minute trace of silver.

*Remark.* JOHN found in this mineral between 1 and 2 per cent. of tellurium. This agrees with the character of the fumes deposited in the glass tube, though, in that case, a larger quantity would be expected than was found by JOHN. Tellurium generally tinges the reducing flame green; this is not the

case with this mineral, which communicates a bluish tinge, if any, to the flame. The same thing takes place with the foliated tellurium (Blättererz) in which tellurium and lead occur together, so that the lead partially changes the characteristic reaction of the tellurium.

*Tin pyrites*,  $\text{Fe}^2\text{Sn} + \text{Cu}^2\text{Sn}$ , (Zinnkies,) from Cornwall.

Alone it melts at full red heat, and smells, in the external flame, of sulphurous acid; it becomes snow-white on the surface and coats the charcoal with a white deposit, both near the globule and at a few lines distance from it. This coating, which is the characteristic test of this mineral before the blowpipe, is the oxide of tin. It is distinguished from that of other volatile minerals, 1st, in being contiguous to the assay, 2d, by not being driven off either by the inner or outer flame, if the blast be not so strong as to drive it away mechanically.

In the open tube it smells of sulphurous acid, and deposits dense white fumes, which are not volatile, upon the assay, and a little distance from it.

Roasted for sometime on charcoal, it gives a brittle metallic globule, which, when treated with the fluxes, gives the reaction of iron and copper. If treated in the reducing flame with a mixture of soda and borax, a pale, hard and imperfectly malleable button of copper is obtained.

*Sulphuret of silver*,  $\text{Ag}$ , (Glaserz,) from Schemnitz.

Alone, on charcoal, it fuses and swells up, and forms empty bubbles, but collects into a globule, after being heated for some time. It smells of sulphurous acid, and leaves, finally, a grain of silver, surrounded with a slag. The slag, fused with borax and salt of phosphorus, indicates the presence of iron and copper.

*Sulphuret of silver and copper*,  $\text{Cu Ag}$ , (Silberkupferglanz.)

Alone it fuses readily, smells of sulphurous acid, does not give off fumes, even in the tube, is not oxidized, neither does it form a liquid slag, either on charcoal or in the tube. The globule has a grey color, and metallic lustre; it is imperfectly malleable, and has a grey fracture. Treated with the fluxes, it gives the reaction of copper. Cupelled with lead, on bone-ashes, it gives a large globule of silver, and the cupel is colored blackish-green.

*Sulphuret of mercury*,  $\text{Hg}$ , *Cinnabar*.

a. *Crystallized cinnabar*, from Almaden in Spain.

Alone on charcoal it volatilizes, leaves no residuum, and does not smell of sulphurous acid.

In the matrass it sublimes. The sublimate is dark colored, and gives a red streak.

Roasted in the open tube, mercury and sublimed cinnabar are obtained. The mercury deposits at a greater distance from the flame, than the cinnabar.

In the matrass globules of mercury are obtained.

b. *Mealy cinnabar*, from Zweibrücken.

Alone in the matrass it gives off cinnabar, and leave a large residuum, which, when treated with the fluxes, shows the presence of a large proportion of iron and lead, and a trace of copper.

c. *Hepatic cinnabar*, (Lebererz.)

Alone in the matrass it gives off cinnabar, and leaves a black residuum. If this be taken out and heated in an open tube, it gradually disappears, without subliming or emitting an odor, till, at length, only a small trace of earthy matter remains. The residuum resembles charcoal.

*Sulphuret of antimony*.  $\text{Sb}$ , (Grauspiesglanzerz.)

Alone on charcoal, it fuses readily, and is absorbed by the coal, of which the surface becomes coated with a black glassy mass. If the heat be continued, particles resembling metal appear on the surface of the charcoal, which seem to be a sulphuret, and do not behave like the pure metal; they do not burn, but become blackened and lose their metallic lustre, before becoming cold.

In the glass tube, it gives, at the commencement of the roasting, a large quantity of antimonious acid, and afterwards a sublimate of antimonious acid, mixed with a large proportion of oxide. This is curious, since the pure metal gives off only oxide, and the sublimate is quite volatile. The air which issues from the tube smells of sulphurous acid.

#### HYPANTIMONIOSULPHUROUS SALTS.

This division embraces a class of minerals which has received a variety of names, (Fahlerz, Weissgültigerz, &c.) and of which the real composition was first made known by the discovery of the sulphur salts.

*Hemi-hypantimoniosulphurous sulphuret of iron*,  $\text{Fe}^2 \text{Sb}^2$ , *Berthierite*, from Chazelles in Auvergne.

On charcoal it fuses readily, gives off fumes of antimony, and leaves, after the antimony has been driven off, a black slag, which is attracted by the magnet, and which gives with the fluxes the reaction of the protoxide of iron.

*Neutral hypantimoniosulphurous sulphuret of lead*,  $\text{Pb Sb}$ , *Zinkenite*, from Wolfsberg, near Stollberg in the Harz.

Alone on charcoal it decrepitates, fuses, gives off fumes of antimony, and can be almost entirely driven off; the residuum, treated with the fluxes, indicates the presence of copper.

In the open tube it gives off dense white fumes, of which a part is volatile, and is the oxide of antimony, the remaining portion is fixed, and is an antimoniate of lead.

It is generally difficult to determine the presence of antimony, if lead and sulphur are present at the same time. According to PLATTNER, the antimony can be obtained tolerably free from lead, by roasting the fused assay with melted boracic acid, taking the precaution not to allow it to be surrounded entirely by the boracic acid. This latter dissolves the oxide of lead, and keeps it back, the sulphur burns and forms sulphurous acid, and antimony is deposited upon the charcoal.

Pb Sb combines with Pb in several distinct proportions, and forms several species of minerals. The following are those known at present:

Plagionite	$3 \text{ Pb Sb} + \text{Pb}$
Jamesonite	$2 \text{ Pb Sb} + \text{Pb}$
Plumose antimony	$\text{Pb Sb} + \text{Pb}$
Bortlangerite	$\text{Pb Sb} + 2 \text{ Pb}$
Geocronite	$\text{Pb Sb} + 4 \text{ Pb}$
Kilbrickenite	$\text{Pb Sb} + 5 \text{ Pb}$

These different species cannot be distinguished from each other by the blowpipe, and the most which can be done is to determine whether the specimen under examination belongs to those containing a larger or smaller proportion of antimony, and whether it contains other metals intermixed; I will subjoin a couple of examples.

*Jamesonite*, from Cornwall, behaves like the preceding, but, after the antimony and lead have been driven off, a slag remains, which gives a trace of the presence of the oxides of iron and copper, when treated with the fluxes.

*Plagionite*, from Wolfsberg.

Decrepitates strongly; in the open tube, gives off fumes of antimony and sulphurous acid. Fuses very readily. It is absorbed by the charcoal, exactly like sulphuret of antimony; and if this part of the charcoal be heated for some time, small globules of lead make their appearance.

It does not give a colored bead with borax.

Treated with salt of phosphorus, in the oxidating flame, it gives a transparent glass, which becomes grey and opaque, on

congealing, like that of bismuth. This property disappears on farther heating, when, by the addition of tin, a dirty red color can be obtained, indicating the presence of copper.

When treated with soda, a hepar is obtained, which sinks into the charcoal, and leaves globules of lead upon the surface. These can be driven off on the cupel, without leaving a visible trace of silver.

*One-third hypantimoniosulphurous sulphuret of lead and copper*,  $\text{Cu}^3 \overset{'''}{\text{Sb}} + 2 \text{Pb}^3 \overset{'''}{\text{Sb}}$ , *Bournonite*, from Bleiberg.

On charcoal, it fuses, and fumes for a short time, and afterwards congeals into a black bead; if strongly heated, fumes of lead deposit on the charcoal. It gives a slaggy mass, which, treated with the fluxes, indicates the presence of a large proportion of copper, and from which a button of copper can be obtained, after clearing it of lead.

Heated in the tube, it smells of sulphurous acid, and gives off dense white fumes, which mostly condense on the lower side of the tube, and cannot be driven off or fused. The part which deposits on the upper side of the tube is volatile. The former consists of antimoniate of lead; the latter, of oxide of antimony.

*Grey copper* (Fahlerz),  $\overset{\text{Fe}^4}{\underset{\text{Zn}^4}{\left\{ \begin{array}{c} \overset{'''}{\text{Sb}} \\ \overset{'''}{\text{As}} \end{array} \right\}}} + 2 \overset{\text{Cu}^4}{\left\{ \begin{array}{c} \overset{'''}{\text{Sb}} \\ \overset{'''}{\text{As}} \end{array} \right\}}$ , from

different localities. (Schwarzerz,) from Kapnick, *Endellionite*, from St. Harvey, near Grenoble, and from Katharinenburg.

Alone, in the open tube, they fuse, and give off fumes of antimony, which contain little antimonious acid, but smell of sulphurous acid, which smell cannot be perceived before the assay has been heated for some time. A piece of Brazil-wood paper inserted into the upper end of the tube is entirely bleached. The roasted substance congeals into a black mass.

On charcoal, they deposit antimony, without any trace of lead; the globule becomes smaller, grey, and semi-malleable; in borax, it remains for some time grey, and then indicates the presence of copper; a grain of copper is obtained by fusion with soda.

*Addition.* a. *Licht-weissgültigerz*, from Freiberg.

It decrepitates strongly, fuses easily, and gives off lead fumes.

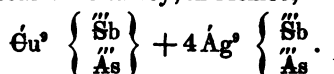
In the open tube, it behaves like the foregoing. The roasted mineral, treated with the fluxes, tinges them with the color of nickel, and sometimes of cobalt. With borax, a metallic bead is obtained, which, cupelled with lead on bone-

ashes, is slightly diminished in size, and leaves on the cupel pure silver.

b. *Dunkel-weissgültigerz*, from Sala.

In the open tube, it behaves like the former variety. It leaves, after being roasted, a slaggy mass, which colors borax with iron, and gives a globule of lead, which, after cupellation, leaves an inconsiderable trace of silver.

*Polybasite*, from Guarisamey, in Mexico,



It decrepitates slightly, and fuses very easily.

In the open tube, it gives a white sublimate, and smells of sulphurous acid.

On charcoal, it does not deposit antimony.

With borax and salt of phosphorus, it gives a glass colored by oxide of copper.

With borax, it forms a hepar, and smells of arsenic. A white regulus is formed in the melted mass.

*Myargyrite*,  $\text{Ag}^* \text{Sb}'''$ , from Braunsdorff.

In the open tube, the assay fuses readily, and gives a considerable sublimate of oxide of antimony, at the same time smelling of sulphurous acid. If the intensity of the flame be increased, a yellow sublimate is formed, which is transparent, and less volatile than the oxide of antimony; so that, after this latter has been driven off, a portion of the yellow sublimate remains. A small quantity of a slightly fused slag forms around the globule.

On charcoal, it fuses and fumes. The deposit, which is formed around the assay, is at first yellow in the centre, which color afterwards disappears.

No color is obtained with borax or salt of phosphorus.

Hepar is formed with soda, which sinks into the charcoal, and leaves a white brittle globule, which, after being heated for some time, leaves a button of pure silver.

*One-third hypantimoniosulphurous sulphuret of silver*,  $\text{Ag}^* \text{Sb}'''$ , (Rothgülden.) Alone, on charcoal, it decrepitates, fuses, burns, and fumes like antimony, but smells of arsenic. The fumes soon cease to be given off.

In the open tube, it fumes considerably, and smells of sulphurous acid, particularly at the beginning of the operation. The greater portion of the fumes condenses upon the glass, and sometimes crystallizes; that it is oxide of antimony, and can be entirely volatilized. The remaining globule gives,



after being heated in the exterior flame, a grain of pure silver.

*Sulphuret of molybdena, Mo.*

Alone, on the charcoal, it smells of sulphurous acid, fumes, and deposits on the coal, especially at first; it is burned with the greatest difficulty, and remains unaltered for a long time during the heating.

With saltpetre, in the platina spoon, it detonates with a flash, and dissolves in the fused salt, leaving a few yellow flocculi, which remain behind on washing the salt, and behave like molybdate of iron before the blowpipe.

In the open tube, it gives no sublimate, but the glass becomes dim around the assay.

*Sulphuret of arsenic. a. red, As, Realgar. b. yellow, As, Orpiment.*

Alone, on charcoal, burns with a whitish-yellow flame. In the open tube, it consumes, and deposits white arsenic in the upper portion of the tube; it volatilizes, and leaves no residuum. In the matrass, it fuses, boils, and gradually sublimes. The sublimate is dark yellow and transparent, and sometimes of a beautiful red.

In legal investigations, it is often of great importance to be able to convert the sulphuret of arsenic into the metal. This sometimes succeeds very well, when the sulphuret is placed at the bottom of a small tube, such as is described on page 55, with a bit of iron wire before it, which is heated to a full red heat, and the sulphuret conducted over it in the gaseous form. The arsenic is reduced, and deposits on the tube in the metallic state. This method, however, so often fails, that it cannot be depended on when small quantities are to be operated with. THIEBEUF lately stated that silver-leaf could be used instead of the iron wire. I have also tried this, but it is still less to be depended on. The effect of the silver on the sulphuret of arsenic, As, is this: that a certain portion of the arsenic is deprived of its sulphur, which unites with the silver, and forms sulphuret of silver, which again combines with the remaining portion, and forms arsenio-sulphurous sulphuret of silver, from which the arsenic cannot be separated by fusion with more silver. For this reason, the operation always succeeds when performed in the following method: the sulphuret of arsenic is placed in an open glass tube, of the thickness of a goose-quill, and about four or five inches long, and roasted by inclining the tube, and heating it directly over the assay, so that the gas which rises passes over the hottest part of the tube

and is burned. The roasting must be slowly carried on, so that nothing shall escape unconsumed. Arsenious acid crystallizes, and collects in one portion of the tube, close by which it is to be drawn out, and the arsenious acid driven into that portion of the tube, and reduced with charcoal. Without a little practice, it will be difficult, at first, to succeed in this operation; but the knack is soon acquired, and, after that, it never fails to succeed.

Sulphuret of arsenic can be fused with soda, and then heated in a stream of hydrogen by means of the blowpipe flame, when arsenic is gradually set free and sublimed. With charcoal, however, no arsenic is obtained.

*Arsenical glance*, (*Arsenikglanz*), from Palmbaum, near Marienberg. (Furnished by Prof. BREITHAUPF.)

Heated in the matrass, it gives off at first brown sulphuret of arsenic, and afterwards metallic arsenic. It sublimes without leaving a residuum.

The presence of sulphur can be recognized in this mineral, by treating it with soda, when it combines with a portion of the soda and blackens silver.

*Remark.* This combination appears to be identical with the artificial brown sulphuret of arsenic  $12 \text{ As} + \text{S}$ .

KERSTEN described another arsenical glance from the same locality, from which arsenic only was sublimed, leaving behind a little bismuth. He could not detect sulphur in it.

*Arseniosulphurous sulphuret of silver*,  $\text{Ag}^+ \text{As}^-$ , (*Sprödglasserz*), from Saxony.

Alone in the open tube it fuses, fumes a little, and deposits on the glass small, lustrous, white crystals of arsenious acid, without a trace of antimony.

On charcoal it leaves no deposit, is slowly roasted, smells slightly of arsenic, if the heat be strong, and retains its sulphur with greater obstinacy than the sulphuret of silver; it leaves a dark grey, metallic globule, which can be hammered out till quite thin, although it cracks on the edges. If treated with a glass of soda and silica, the glass acquires a hepatic color, and the silver becomes pure.

By the addition of soda, the roasting and consequent purification of the silver is hastened. The silver can, however, be obtained pure in a strong oxidating flame, without soda, so that it can be clearly seen that the foreign substances in the globule were volatile.

With the fluxes, the characteristic reaction of silver only is obtained.

*Remark.* The difference in the strength with which the silver retains the sulphur in combination, in the sulphuret of silver (Glaserz), and the brittle sulphuret (Sprödglasserz), is so remarkable, that it is evident that it must be occasioned by the presence of some third substance. KLAPROTH found ten per cent. of antimony in the brittle sulphuret of silver from Saxony. I could not find a trace of it; and, on the contrary, if antimony is present, the sulphur is separated with the greatest ease, and antimoniuuret of silver is obtained. I fused silver with the sulphuret of arsenic, however, and obtained a combination which had all the properties of the brittle sulphuret; and I feel confident that it is a combination of sulphur and the arseniuret of silver, and that the presence of arsenic is the reason that the sulphur is burned off with such difficulty.

It must also be remarked, that there are specimens of the brittle sulphuret, in which the sulphuret of arsenic is partially replaced by sulphuret of antimony. These give, according to VON KOBELL, a deposit of antimony upon the charcoal. H. ROSE analyzed a specimen of the brittle sulphuret of silver from Schemnitz, which contained antimony only =  $\text{Ag}''\text{Sb} + 5 \text{Ag}$ .

#### ARSENIO-SULPHURETS.

*Arsenio-sulphuret of iron*,  $\text{Fe S}^2 + \text{Fe As}^2$ , *Mispickel*, crystallized, from various localities.

Alone, in the matrass, it gives off at first a red sublimate, which is sulphuret of arsenic, and afterwards a black one, and, finally, metallic arsenic, in the form of a brilliant, metallic, greyish, crystalline sublimate. The ignited assay no longer smells of arsenic, if treated on charcoal, and behaves like magnetic pyrites. On charcoal, mispickel gives off, at first, dense fumes of arsenic, and afterwards fuses, with the odor of arsenic, into a globule, which behaves like fused magnetic pyrites. If the mispickel contains cobalt, the presence of this metal is detected, by strongly roasting the assay, and then dissolving it in the reducing flame with borax or salt of phosphorus; the cobalt color then becomes visible, after the bead has become cool.

*Arsenio-sulphuret of cobalt*,  $\text{Co S}^2 + \text{Co As}^2$ , (*Glanzkobalt*), from Tunaberg.

Heated in the matrass alone it undergoes no change.

In the open tube it is slowly roasted, gives off, when strongly

- heated, arsenious acid, smells of sulphurous acid, and bleaches Brazil-wood paper.

On charcoal it fumes strongly, and after being roasted for some time it becomes liquid. Afterwards it behaves like fused arsenical cobalt.

*Arsenio-sulphuret of nickel*,  $\text{Ni S}^2 + \text{Ni As}^2$ , (Nickelglanz,) from Loos.

Alone in the matrass it decrepitates strongly, and gives off, on ignition, a large quantity of sulphuret of arsenic, which sublimes in a fused, transparent, yellowish brown mass, which remains transparent after congealing. The ignited assay resembles copper nickel, and reacts in the same manner with the fluxes. The presence of iron is detected with difficulty, and the cobalt-blue color is generally observed, after the nickel has been removed by reduction.

## OXYGEN AND OXIDIZED SUBSTANCES.

### A. OXIDES OF ELECTRO-POSITIVE METALS.

#### *Peroxide of manganese*, $\text{Mn}$ .

Heated alone in the matrass it undergoes, when pure, no apparent change, but, generally, even the best crystallized specimens are more or less mixed with the hydrated oxide, from which the water is driven off by heat, so that the quantity of water given off furnishes a standard of the economical value of the ores of manganese. The larger the quantity of water which they give off, the less their value, since they contain proportionally less of the peroxide. — Heated on charcoal with a strong reducing flame it becomes reddish brown.

It is dissolved by borax and salt of phosphorus with strong effervescence, which is caused by the escape of oxygen; it behaves, in general, like pure oxide of manganese. The peroxide of manganese is often contaminated with iron, which can be recognized by treating it with borax in a strong reducing flame. The color of the iron only remains. Also, by reduction with soda and washing, the iron is obtained.

*Sesquioxide of manganese*,  $\text{Mn}$ , and *Red oxide of manganese*,  $\text{Mn} + \text{Mn}$ , behave exactly like the foregoing.

The oxides of manganese often contain small quantities of

alkalies, baryta, or lime. Care must be taken, therefore, after thoroughly roasting the assay, to moisten it with a few drops of water on platina foil, and then examine whether the water blues reddened litmus-paper.

*Franklinite*,  $\dot{R} \ddot{R}$ , (in which  $\dot{R}$  represents a mixture of  $\dot{Zn}$ ,  $\dot{Mn}$ , and  $\dot{Fe}$ ,  $\ddot{R}$  a mixture of  $\ddot{Mn}$  and  $\ddot{Fe}$ .)

Alone, it is infusible.

It dissolves in borax and salt of phosphorus, and tinges the glass on the platina wire in the outer flame with the usual color of manganese, and on charcoal in the interior flame, with that of the protoxide of iron.

On platina, with soda, the fused mass is green. The assay deposits fumes on the charcoal.

The *pale red mineral*, which occurs with Franklinite, gives the following reactions:—

Alone, it remains unchanged, except that it acquires a deeper color when hot. In the reducing flame, it coats the charcoal with a deposit of zinc.

It is readily dissolved by borax, and imparts to it the characteristic color of manganese in the outer flame. The saturated solution is rendered opaque on cooling, and by the intermittent flame.

It is readily dissolved by salt of phosphorus, and gives a transparent bead. The color of manganese cannot be obtained till the glass has dissolved so large a quantity that it is no longer transparent on cooling.

It is not dissolved by soda, and no metal can be obtained by reduction; on the platina foil it gives a green color, but not particularly striking.

With the solution of cobalt, the powder (which is yellow) acquires a yellowish green tint on the exterior, but does not become bluish-green or fuse on the edges.

*Peroxide of iron*,  $\ddot{Fe}$ , *Specular iron*, *Bloodstone*, (*Eisenglanz*.)

Its behavior was described under the head of the oxide of iron. It sometimes occurs contaminated with chromium and titanium. These mixtures are easily detected by methods which will be described under the head of chromate of iron and titanate of iron.

*Magnetic oxide of iron*,  $\dot{Fe} + \ddot{Fe}$ .

This oxide behaves exactly like the preceding.

*Red oxide of copper*,  $\dot{Cu}$ , and the

*Protoxide of copper*,  $\dot{Cu}$ , behave as was described under the oxide of copper, in the first division of the work.

*Protoxide of lead*,  $\text{Pb}$ , and

*Superoxide of lead*,  $\text{Pb}$ , *Minium*.

Both these behave as was described under the oxide of lead.

*Peroxide of bismuth*,  $\text{Bi}$ .

Its behavior is similar to that described under oxide of bismuth in the first part of the book. Sometimes traces of iron and copper are found in it.

It sometimes smells distinctly of arsenic when reduced with soda, and if any quartz, to which it often is found adhering, is present, it fuses slowly into a glass which becomes yellowish and opaque on cooling.

*Peroxide of tin*,  $\text{Sn}$ , *Tinstone*.

See oxide of tin. On platina foil with soda the dark varieties give traces of manganese.

*Remark.* When the oxide of tin contains tantalum, as in the variety found at Finbo, near Fahlun, the presence of this metal renders the tin difficultly and imperfectly fusible, and a large residuum is obtained. Its solution in borax, at a certain degree of saturation, acquires the property of becoming opaque by flaming, or even of itself.

## B. OXIDES OF ELECTRO-NEGATIVE SUBSTANCES.

### WATER AND HYDRATES.

*Hydrate of magnesia*,  $\text{Mg H}$ , from Hoboken and Unst.

Alone, in the matrass, it gives off water, and both before and after ignition restores the blue color of reddened litmus-paper. On charcoal it thickens in the direction of the lamina and cracks, and turns milk-white, but does not fuse.

With the fluxes and solution of cobalt, it behaves like pure magnesia.

*Hydrate of the oxide of manganese*,  $\text{Mn H}$ , *Wad*.

Alone, in the matrass, it gives off a large quantity of water. On charcoal, and with the fluxes, it behaves like the oxide of manganese.

*Addition.* a. *Cupreous manganese*, (Kupfermanganerz,)

$\text{Cu Mn}^2 + 2\text{H}$ , (in which about half of Cu is replaced by Mn, K, Ba, Ca, Mg and Co.) from Schlackenwald.

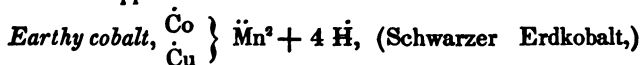
Alone, in the matrass, it gives off at first a quantity of water, and then splits in pieces with decrepitation. The water has not an acid reaction.

On charcoal it becomes brown in the reducing flame, but does not fuse.

It is readily dissolved by borax, and gives, in the reducing flame, a transparent, colorless glass, which becomes red and opaque on cooling.

It is readily dissolved by salt of phosphorus, and gives the same shades of color as with borax. If the reduced colorless glass be held for a moment in the oxidating flame, it acquires a beautiful copper-green tint, and remains transparent after cooling. If more strongly oxidized, it acquires a blue amethystine color.

It is not dissolved by soda, but if borax be added, a distinct globule of copper is obtained.



from Saalfeld.

Alone it gives off water, which has an empyreumatic odor.

On charcoal it smells feebly of arsenic, and does not fuse.

It is dissolved by borax and the salt of phosphorus, with the usual color of cobalt, which is so intense that it prevents any other reaction from being distinguished.

It is not dissolved by soda. On the platina wire it gives a mass intensely colored by manganese. If the clear green soda be separated, and treated alone on charcoal, a white, slightly magnetic metal is obtained, which imparts the characteristic color of iron to salt of phosphorus, and also the property of becoming milk-white on cooling. I have not examined it farther.

*Hydrate of the peroxide of iron,  $\text{Fe}^2 \text{H}^2$ , (Ochre, Stilpnosiderite, Lepidocrocite, Bog iron ore, &c.)*

Gives off water in the matrass, and leaves red oxide of iron. Stilpnosiderite can be fused on the edges in a strong heat. After being dissolved with salt of phosphorus in a strong reducing flame, it gives with tin a trace of copper.

*Hydrate of the oxide of uranium,  $\text{U} \text{H}^2$ , from various localities.*

a. *Uranium ochre*, a loose, lemon-yellow powder.

Gives off water in the matrass, becomes red as long as it remains hot, and green in the reducing flame, without fusing. It reacts, in general, like pure oxide of uranium.

b. *Compact oxide of uranium.* Alone in the matrass it gives off water, and acquires a reddish tinge. On charcoal it melts in a strong flame, and the fused assay is then black. It behaves like the former with the fluxes.

With soda it gives fumes of lead and white metallic globules.

## ALUMINA AND ALUMINATES.

*Alumina,  $\ddot{\text{Al}}$ , Telesie, Corundum, Sapphire, Ruby, &c.*

Alone, it remains entirely unchanged, either in powder or in fragments.

It is slowly dissolved by borax into a transparent, colorless glass, which cannot be rendered opaque by flaming.

It is with difficulty dissolved by the salt of phosphorus; for this purpose the assay must be finely pulverized, when it slowly dissolves into a transparent glass. The undissolved portion, in case more has been added than the flux could take up, does not become opaque, as is the case with the silicates, and the bead is not opalescent, either on cooling, or when slightly heated in the exterior flame.

It is not attacked by soda, and no sign of fusion can be perceived.

With the solution of cobalt, it gives a deep blue. The color is beautiful in proportion as the assay is finely pulverized, and as the heat is stronger and more constant, since the oxide of cobalt attacks the alumina when in this state, very slowly.

*Hydrate of alumina. a. Diaspore,  $\ddot{\text{Al}}\ddot{\text{H}}$ .\**

Alone, in the matrass, it decrepitates with great violence, and crumbles into small, brilliant, white scales. During the decrepitation it gives off very little water, but afterwards a considerable quantity, which renders it probable that it retains the water with strong chemical affinity, as is generally the case with the hydrates. On charcoal it is infusible.

The scales are dissolved by borax with considerable facility, into a clear, colorless glass, without giving a skeleton of silica.

They are not at all acted on by soda.

With borax and iron they do not indicate the presence of phosphoric acid.

They acquire a beautiful blue color with the solution of cobalt.

*Diaspore*, from Kosoibrod in Siberia, does not decrepitate, gives off a large quantity of water, and turns brown after ignition, showing a grey foliated structure alternating with a dark red, earthy mass.

It is gradually and entirely dissolved by borax and salt of

\* The locality of the diaspore here described is unknown, and only one specimen of it is known, which Le Lièvre bought of a French mineral dealer, and which Haüy used in making his description of diaspore. The piece which was used for examination with the blowpipe, was broken from the same specimen.



phosphorus; the glass acquires the color of the oxide of iron, and the undissolved portion has a white color.

Soda does not attack it, but sinks into the charcoal, and leaves the alumina tolerably white.

b. *Gibbsite*,  $\text{Al H}^3$ , from Richmond, in Massachusetts.

Alone, in the matrass, it gives off a large quantity of water. On charcoal it is infusible, and behaves with the fluxes like pure alumina. With the solution of cobalt it gives a beautiful blue.

*Aluminate of magnesia*,  $\text{Mg Al}$ , *Spinel*, from Celon and from Åker.

Alone, it undergoes no change. The red variety from Ceylon becomes darker and opaque while hot, but on cooling it gradually acquires its former color. When seen by transmitted light it loses its fine chrome-green color, becomes nearly colorless, and ends by acquiring its original red.

It is slowly dissolved by borax into a clear and almost colorless glass. The spinel from Åker often contains lime in its interstices; in that case it dissolves with effervescence, and gives a glass which can be rendered opaque by flaming.

In fragments it is slowly dissolved by salt of phosphorus, but when pulverized it dissolves readily and entirely. The bead shows the color of iron, but the spinel from Ceylon becomes faintly but distinctly chrome-green on cooling, and does not become opalescent.

It is not dissolved by soda, but it swells up; on platina foil it shows faint traces of manganese.

*Aluminate of the protoxide of iron and magnesia*,  $\left. \begin{matrix} \text{Mg} \\ \text{Fe} \end{matrix} \right\} \text{Al}$ ,

*Pleonaste*, from Ceylon and Monte Somma.

Alone, it does not change except by becoming blue in a strong heat, resembling the blue, glassy slag of the blast-furnaces. It does not fuse, even when pulverized, but appears glassy on the edges.

It is dissolved by borax into a transparent, dark and clear iron-green glass.

It is hardly attacked by salt of phosphorus unless previously pulverized, but it is then easily and entirely dissolved into a transparent glass tinged with iron.

With soda it swells up into a black slag, which does not fuse even on the addition of more soda.

*Remark.* *Chlorospinel*, from Slatoust, behaves like the last mentioned. With salt of phosphorus the presence of copper

can be detected by the aid of tin. When the saturated glass of borax is treated on charcoal, scales of copper can be separated by washing in the usual manner.

*Aluminate of zinc,*  $\left. \begin{matrix} \text{Zn} \\ \text{Fe} \end{matrix} \right\} \ddot{\text{Al}}, \text{Gahnite, from Fahlun and}$

Franklin.

Alone, it undergoes no change.

It is so little acted on by borax and salt of phosphorus, that it appears as if no part of it had been dissolved; even when pulverized it is very slightly dissolved.

It is not dissolved by soda, but forms a dark colored slag. If this be pulverized, the finer the better, and well mixed with soda, a distinct ring of oxide of zinc deposits around the assay when it is strongly heated in the reducing flame. This is the best characteristic of Gahnite before the blowpipe.

It is dissolved by soda and borax together into a transparent glass, which is colored by iron.

#### SILICA, IN THE FORM OF QUARTZ, ROCK-CRYSTAL, HORNSTONE, CHALCEDONY, CARNELIAN, FLINT, &C., AND SILICATES.

I shall not give a particular account of the behavior of all these different varieties, since small proportions of the metals often cause their reaction with the fluxes to differ. The principal characteristic is that already described under the head of silica. Some, like opal and pitchstone, give off water when heated in the matrass. This water, however, appears to be merely hygrometric moisture, as is the case with the dry lumps of silica obtained by the operations of analysis, in which the proportion of water varies with the hygrometric state of the atmosphere. Flint, which often includes calciferous petrifications, can be melted in those places, since silicate of lime is formed. According to TURNER, the varieties of pitchstone from Arran and Meissen, treated with bisulphate of potash and fluor spar, tinge the flame green, indicating the presence of boracic acid.

#### I. SILICATES WITH ONE BASE.

*Neutral silicate of lime,*  $\text{Ca}\ddot{\text{Si}}, (\text{CS}^3),^*$  from Aedelfors and Gjellebäk, and

\* Since the mineralogical, or more strictly speaking, the empirical formulæ, present in a more simple manner the composition of the silicates, I shall give both kinds of formulæ with the silicates.

*Two-thirds silicate of lime*,  $\text{Ca}^3\text{Si}^2$ , ( $C S^2$ ), *Table spar*, from Nagyag, Perhoniemi, Pargas, Gökum, and Capo di Bove.

Alone in the matrass they undergo no change. On charcoal they fuse on the edges to a semi-transparent, colorless bead. They require a strong heat for fusion, and sometimes puff up. The mineral from Gjellebäk gives a reddish glass, and is more difficultly fusible.

They are readily dissolved by borax into a transparent glass, which cannot be rendered opaque by flaming.

They are dissolved by the salt of phosphorus, and leave a siliceous skeleton resembling iron. The glass generally becomes opalescent on cooling.

With a certain proportion of soda they are dissolved to a blebby glass; if more be added they become infusible, and swell up. Table spar remains colorless, but the mineral from Gjellebäk acquires a reddish tinge. The latter becomes green on platina foil. With the solution of cobalt they are far more fusible; the fused edge is blue.

*Persilicate of lime, Okenite*, from Greenland,  $\text{Ca}^3\text{Si}^4 + 6\text{H}$ , ( $C S^4 + 2 Aq$ ).

In the matrass it gives off a large quantity of water, without changing its appearance.

In the forceps it fuses to a glass, which is milk-white on cooling.

It is slowly but perfectly dissolved by borax; the glass is transparent and colorless.

It is much more slowly dissolved by salt of phosphorus, and does not give a siliceous skeleton. The undissolved portion is rounded and milk-white. If, however, the mineral be finely pulverized, it gives an ice-grey skeleton of silica, and an opalescent glass.

It dissolves with soda into a clear, transparent glass, which becomes opaque and milk-white on cooling. If a large excess of soda be employed, the excess sinks into the charcoal, and leaves an infusible slag. With soda on platina it dissolves into a transparent glass, which becomes milk-white on hardening, and after cooling inclines to green.

With cobalt the fused edges only are blue; the assay, however, is rendered less fusible by the addition of the oxide of cobalt.

*Neutral silicate of magnesia*,  $\text{Mg}\ddot{\text{Si}}$ , ( $M S^3$ ), *Soapstone*, from Wunsiedel, and

*Neutral silicate of magnesia with water*,  $\text{Mg}\ddot{\text{Si}} + 2\text{H}$ , ( $M S^3 + 2 Aq$ ), *Meerschaum*, from Turkey and from Valeros in Spain.

Alone in the matrass they give off water, smell burnt and blacken. Meerschaum gives considerably more water than soapstone.

On charcoal they burn white again, shrivel together, and fuse on the thinnest edges into a white enamel.

They are readily dissolved by borax into a transparent glass.

They are decomposed by salt of phosphorus, leaving a siliceous skeleton, which is transparent. The clear, colorless glass crystallizes on cooling. With a sufficient quantity of soda they fuse to a transparent glass; if there is too little or too much soda, the bead is opaque.

With the solution of cobalt they give a clear lilac color.

*Two-thirds silicate of magnesia, Picrosmine*,  $2 \text{Mg}^3 \ddot{\text{Si}}^2 + 3 \text{H}$ , ( $2 \text{MS}^2 + 3 \text{Aq}$ ), from Engelsberg, near Presnitz, in Bohemia.

Alone in the matrass it gives water, blackens and smells burnt. On charcoal it burns white without fusing.

Borax slowly dissolves it into a transparent glass.

Salt of phosphorus separates a siliceous skeleton, and gives a colorless glass.

It fuses imperfectly with soda into a glass.

With solution of cobalt it gives a pale and indistinct red.

*Picrophyll*,  $\text{Mg}^3 \ddot{\text{Si}}^2 + 2 \text{H}$ , ( $3 \text{MS}^2 + 2 \text{Aq}$ ), from Sala.

*Aphrodite*,  $4 \text{Mg}^3 \ddot{\text{Si}}^2 + 9 \text{H}$ , ( $4 \text{MS}^2 + 3 \text{Aq}$ ), from Långbanshyttan.

*Monradite*,  $4 \text{Mg}^3 \ddot{\text{Si}}^2 + 3 \text{H}$ , ( $4 \text{MS}^2 + \text{Aq}$ ), from Bergens Stift, Norway. All these behave like picrosmine. Monradite has a part of its magnesia replaced by protoxide of iron, and for this reason gives with the fluxes the shades of color characteristic of iron. All these magnesian silicates give, with a small proportion of soda, a transparent, blebby glass; but if the proportion of soda be increased, they swell up into an infusible slag.

*Pyralloolite*, from Pargas, which consists principally of  $\text{Mg}^3 \ddot{\text{Si}}^2$ , but gives the formula  $\text{CS}^4 + 6 \text{MS}^2 + \text{AS}^2 + 2 \text{Aq}$ , according to NORDENSKJÖLD'S analysis; it behaves like picrosmine, but becomes rounded on the edges if the heat is strong, and gives with soda a glass which is transparent, and tinged by iron.

*Two-thirds silicate of magnesia, with hydrate of magnesia, Serpentine*,  $2 \text{Mg}^3 \ddot{\text{Si}}^2 + 3 \text{Mg} \ddot{\text{H}}^2$ , ( $2 \text{MS}^2 + \text{MAq}^2$ ). In this formula, the magnesia in the silicate is often partly replaced by Fe, which gives the serpentine its green and yellow colors.

a. *Precious serpentine*, from Skyttgrufva, near Fahlun.

Alone in the matrass it gives off water and becomes black.

On charcoal it burns white, and can be melted on its thin edges, in a strong flame, into an enamel.

With borax it dissolves slowly into a transparent, greenish glass.

It behaves like the last described mineral with salt of phosphorus.

With a certain proportion of soda, it forms with difficulty an enamel-white, semi-fluid mass; with a larger quantity, it swells up and becomes infusible.

With the solution of cobalt it gives a red color.

b. *Common serpentine*, yellow and translucent variety from Sala and Baireuth.

Alone in the matrass and on charcoal, it behaves like the preceding.

Borax dissolves it slowly, but in large quantity, and forms with it a glass, which can be rendered opaque by flaming.

With salt of phosphorus, soda and solution of cobalt, it behaves like the preceding.

*Hydrophite*, (serpentine containing vanadium,) from Faberg in Småland, behaves like the former, but gives with borax and salt of phosphorus, in the reducing flame, a greyish-green salt.

*One-third silicate of magnesia, Olivine*,  $\text{Mg}^2\text{Si}$ , in which Mg is replaced by Fe in any proportion.

Alone it gives no water, becomes darker colored, especially on the edges, but does not fuse, and retains its translucency and color. Olivine which has been long exposed to the weather, gives, in the matrass, a considerable quantity of water.

With borax and salt of phosphorus, it behaves like the last described mineral; the glass is colored with iron, and does not indicate the presence of manganese when treated with saltpetre.

With soda it fuses into a brown, slaggy mass.

*One-third silicate of zinc*,  $2\text{Zn}^2\text{Si} + 3\text{H}$ , ( $2\text{ZnS} + \text{Aq}$ ), *Electric calamine*, (Zinkkieselerz.)

Alone in the matrass it decrepitates, gives off water and becomes milk-white, does not fuse, but puffs up a little in a strong heat.

It is dissolved by borax into a transparent glass, which does not become opaque by flaming or on cooling.

With salt of phosphorus it fuses into a transparent glass, which becomes opaque on cooling. If a larger proportion of the assay be employed, traces of silica are seen in the bead.

It is not dissolved by soda, but swells up, and gives, but not readily, fumes of zinc.

With the solution of cobalt, at a moderate temperature, it

becomes green, but when strongly heated the assay acquires a beautiful light-blue color on its edges, and shows signs of fusing, while the blue color extends into the infusible portion.

*Two-thirds silicate of the protoxide of manganese,  $Mn^3\ddot{Si}^2$ , ( $mn\ S^2$ ),\** (Rubinspath, Rothbraunsteinerz,) from Långbanshyttan.

Alone in the matrass it undergoes no change. On charcoal it does not change till it begins to melt, when it gives in the reducing flame a semi-transparent glass, of the color of the mineral; in the oxidating flame, however, it forms a black bead having a metallic lustre, from which the color can be discharged in the reducing flame.

With borax in the reducing flame, it dissolves into a colorless glass; in the oxidating flame the bead has an amethystine color.

It is slowly attacked by the salt of phosphorus, leaves a siliceous skeleton, and gives a colorless glass, which acquires an amethystine color in the exterior flame.

With a certain proportion of soda, it dissolves into a black glass; with a larger quantity, it gives an infusible black slag, and with still more, it is absorbed by the charcoal.

*One-third silicate of manganese,  $Mn^3\ddot{Si} + 3\dot{H}$ , ( $mn\ S + Aq$ ),* (schwarzer Mangankiesel,) from Klapperud, in Dahlsland.

Alone in the matrass it gives a large quantity of water, which has no acid reaction, and afterwards emits an empyreumatic, gaseous vapor, and the black color of the mineral changes to a light grey. Heated to redness, it swells up, and its color becomes still lighter. On charcoal it intumesces, and afterwards fuses to a glass, which has a bottle-green color in the reducing flame, and is black and has a metallic lustre in the oxidating flame.

It is readily dissolved by borax. The glass is strongly colored by oxide of manganese in the exterior flame, and slightly tinged by the protoxide of iron in the reducing flame.

It is dissolved by salt of phosphorus into a colorless glass, which acquires an amethystine color in the exterior flame, leaving a skeleton of silica.

A certain proportion of soda dissolves it into a black glass; a larger quantity gives a black slag, while the flux is absorbed by the charcoal.

*One-ninth silicate of the sesquioxide of manganese,  $\ddot{Mn}^3\ddot{Si}$ , ( $Mn^3\ S$ ),* from Piedmont.

Alone in the matrass it remains unchanged. On charcoal it

\* This mineral can be classed with pyroxene, on account of the small quantity of lime which it contains.

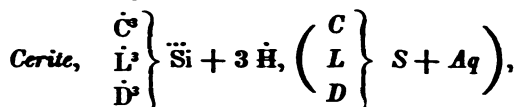
fuses on the edges at a very high temperature, and retains its dark grey color.

Borax dissolves it readily. In the exterior flame it acquires an amethystine color, and in the inner flame a faint tinge of the protoxide of iron.

It dissolves readily with effervescence with the salt of phosphorus, and the bead has a deep amethystine color. In the reducing flame, the glass becomes colorless, and leaves a siliceous skeleton uniformly divided through the mass, and is strongly opalescent on cooling.

Soda does not dissolve it.

*One-third silicate of the protoxide of cerium, oxide of lanthanum, and oxide of didymium,*



from Bastnäs, near Riddarhyttan.

Alone in the matrass it gives off a large quantity of water, and becomes quite opaque. On charcoal it cracks, but does not fuse.

It is slowly dissolved by borax; in the oxidating flame a deep yellow glass is obtained, of which the color grows lighter on cooling, and this light yellow bead can be rendered milk-white by flaming. In the reducing flame the glass has a faint tinge of iron.

The oxide of cerium is taken up by the salt of phosphorus with the usual play of colors. The glass becomes colorless on cooling, and silica remains undissolved, in the form of a white, opaque skeleton.

It is not dissolved by soda, but partially fuses into a dark yellow, slaggy mass.

*Anthosiderite,  $\ddot{\text{Fe}} \ddot{\text{Si}}^2 + \text{H}$* , from Minas Geraes, in South America.

In the matrass it gives off water.

Exposed to the flame alone, the yellowish-brown color of the assay changes at first to a reddish-brown, and then to black. Thin splinters fuse with considerable difficulty into an iron-grey slag, which has a metallic lustre, and is attractable by the magnet.

It is not dissolved by borax or salt of phosphorus, even after being pulverized; but it communicates to these fluxes a tinge of the characteristic color of iron.

*It gives a black glass with soda.*



*Hisingerite*,  $\text{Fe}^3 \ddot{\text{Si}}^3 + 3 \ddot{\text{Fe}} \ddot{\text{Si}} + 15 \dot{\text{H}}$ , ( $F S^3 + 3 F S + 5 Aq$ ), from Riddarhyttan, Bodenmais and Gillinge.

*Sideroschisolite*,  $\text{Fe}^3 \ddot{\text{Si}} + \text{Fe}^3 \dot{\text{H}}^2$ , ( $3 F S + F^3 Aq^2$ )? from Conghonas di Campo, and

*Chlorophaeite*, a silicate of iron, from Ferrö, not yet analyzed, filling spherical cavities; these minerals behave as follows:

The two first give off water when heated in the matrass. They do not fuse, or undergo any change when heated on charcoal, but become magnetic.

They are slowly dissolved by borax and salt of phosphorus, and give beads strongly tinged with iron.

They fuse to a black glass with soda.

The latter contains no water, but fuses to a black glass, and in other respects behaves like the two former. Neither of them gives any trace of manganese, when treated with soda on the platina foil.\*

*Pitchblende*,  $\ddot{\text{U}} \ddot{\ddot{\text{U}}}$ , (Uranpecherz,) from Johann Georgenstadt.

Alone it does not fuse, but held in the forceps it colors the exterior flame green.

With borax and salt of phosphorus it behaves like the oxide of uranium.

It is not dissolved by soda, but emits the smell of arsenic, and gives white metallic globules of iron and lead, by reduction in the usual way.

*Two-thirds silicate of the oxide of copper*,  $\dot{\text{Cu}}^3 \ddot{\text{Si}}^2 + 3 \dot{\text{H}}$ , ( $\text{Cu } S^2 + Aq$ ), *Diopase*, from the country of the Kirghese.

Alone in the matrass it gives off water, and turns black. On charcoal it becomes black in the outer flame, and red in the inner flame, without fusing.

It is readily dissolved by borax, with indications of the presence of copper. The bead has the property of tinging the exterior flame green for an instant, when gently heated in it, which phenomenon is not repeated, if the heat be continuously applied; but if the bead be first allowed to cool, and then be heated again, the same color will be communicated to the flame. This is not the case with pure oxide of copper. In a

\* Under the name of *Hisingerite*, I have included another mineral, from the iron mine Gillinge in Södermanland, which is principally a hydrated silicate of the protoxide of iron, mixed, according to HISINGER'S Analysis, with a small amount of alumina. Its behavior before the blowpipe is as follows:

Alone in the matrass it gives off water; on charcoal or in the forceps it swells up and ramifies, and then fuses to a black glass with a dull surface.

Borax and salt of phosphorus dissolve it readily, giving the reaction of iron; in the salt of phosphorus a siliceous skeleton remains.

With soda it gives a black glass, and becomes green on platina foil.



strong reducing flame, a grain of metallic copper is obtained from the borax glass, and the bead can be rendered colorless by heating.

It is readily dissolved by salt of phosphorus, giving the reaction of copper, but leaves a siliceous skeleton, which can be best seen when the glass is heated in the exterior flame and then allowed to cool. The flame is not colored when this flux is used.

It dissolves with soda into a dark opaque glass, which becomes red internally on cooling, and envelopes a grain of copper. With a larger proportion of soda, it is absorbed by the charcoal, and leaves metallic copper on its surface.

*One-third silicate of the oxide of copper*,  $\text{Cu}^3 \ddot{\text{Si}} + 3 \ddot{\text{H}}$ , ( $\text{Cu S} + \text{Aq}$ ), *Chrysocolla*, (Kieselmalachit,) from Siberia.

It behaves, in all respects, like dioptase. The only noticeable difference is, that the dioptase requires more soda before it sinks into the charcoal, and that the copper can be reduced in the chrysocolla bead so that it becomes colorless.

*Remark.* When dioptase or chrysocolla are treated with the fluxes without being previously ignited, they dissolve with effervescence, which is occasioned by the escape of water and by the presence of carbonic acid, which is not uncommon in the chrysocolla.

*One-third silicate of glucina*,  $\ddot{\text{G}} \ddot{\text{Si}} (\text{GS}^2)$ , *Phenakite*.

Gives off no water. It is infusible and unchangeable, even after being pulverized.

Borax attacks it so slowly, that it appears to be insoluble in that flux. When pulverized, however, it dissolves readily into a transparent glass. If the glass is strongly saturated, on being flamed it exhibits flocks, which do not easily dissolve when the bead is remelted.

Its behavior with salt of phosphorus is the same.

With a small portion of soda, it fuses to a milk-white bead, which swells up on the addition of a larger quantity, and becomes a white, infusible slag.

It does not give a blue color with cobalt.

*Neutral silicate of alumina*, *Agalmatolite*, from China,  $\ddot{\text{Al}} \ddot{\text{Si}}^3 (\text{AS}^3)$ , according to Lychnell; Klaproth and Vauquelin, however, found in it between six and seven per cent. of potash, and Rammelsberg gives, according to their analyses, the formula  $(\ddot{\text{K}} \ddot{\text{Si}} + \ddot{\text{Al}} \ddot{\text{Si}}^3) + 3 (\ddot{\text{Al}} \ddot{\text{Si}} + \ddot{\text{H}})$ . The agalmatolite is probably found in different localities in China, and varies in composition. That used for blowpipe examination in this case was taken from a Chinese image.

Alone in the matrass it gives off water, which smells burnt. The assay turns black, as is generally the case with serpentine and silicates of magnesia. On charcoal, it burns white, becomes covered with fine scales on the surface, and exhibits on the edges signs of fusion.

With borax, it dissolves with effervescence into a transparent, colorless glass; a portion remains undissolved at first, which afterwards dissolves very slowly without effervescence.

Salt of phosphorus does not decompose it. It effervesces strongly, after which the fragment, a little diminished in size, remains entirely infusible.

With a little soda, it fuses to a clear glass; with a larger quantity, it gives a clouded bead, which does not easily liquefy. It gives a beautiful blue with the solution of cobalt.

WACKENRODER analyzed a Chinese image, of which the composition can be represented by  $\text{Mg H} + 5 \text{ Mg Si}$ . This might have been a kind of steatite, and, as such, would give the usual reaction of the silicates of magnesia with the solution of cobalt.

#### *Basic silicates of alumina.*

*Wörthite*,  $\text{Al H} + 5 \text{ Al Si}$  ( $A \text{ Aq} + 5 A \text{ S}$ ), from Petersburg.

*Bamlite*,  $\text{Al Si} + \text{Al}$  ( $A^2 \text{ S}^2$ ), from Bamle, in Norway.

*Xenolite*,  $\text{Al Si} + 2 \text{ Al}$  ( $A \text{ S}$ ), from Peterhoff.

*Andalusite*, *Chiastolite*, *Fibrolite*,  $\text{Al Si} + 3 \text{ Al}$  ( $A^2 \text{ S}^2$ ), from various localities.

*Kyanite*, *Disthène*, *Rhätizite*,  $2 \text{ Al Si} + 7 \text{ Al}$  ( $A^2 \text{ S}^2$ ), from various places.

All these minerals, with trifling exceptions, behave alike.

Alone they undergo no change when ignited, but at a high temperature they become white, without fusing. Their powder is also infusible. Rhätizite becomes red at a moderate heat, but if the temperature be raised it changes to white. Wörthite gives off water in the matrass.

They are gradually dissolved by borax into a transparent, colorless glass.

With salt of phosphorus they are partially dissolved, and leave a blebby, semi-transparent skeleton of silica. The bead is not particularly opalescent on cooling.

With a certain proportion of soda they fuse to a blebby, semi-transparent, rounded mass. If kyanite be heated with soda till it begins to fuse, the mass acquires a faint rose-red

tinge, and the colored portion is transparent. The color disappears at a high temperature and in the interior flame, and cannot be restored by heating in the outer flame. This color is best obtained by a larger proportion of soda on the platina wire, since the soda is liable to be absorbed by the charcoal, before it can act upon the assay. The red color is far more evident in the kyanite of St. Gothard than in specimens from Norway, and with the rhätizite the glass has a yellowish tinge only. With a larger proportion of soda they swell up and do not fuse.

With the solution of cobalt, at a high temperature, they give a fine dark-blue color.

*Addition. Varieties of clay.*

a. *Fuller's earth*, from England.

Alone in the matrass it gives off water, becomes at first lighter and then darker, and emits an empyreumatic odor. The water has a slight ammoniacal reaction. On charcoal it splits in pieces violently, unless very slowly heated. It burns white, and fuses into a white blebby glass.

It is dissolved by borax with difficulty, so that the last remaining portion requires long-continued blowing before it becomes perfectly dissolved. The glass is clear and colorless.

Salt of phosphorus dissolves it into a transparent glass, leaving a siliceous skeleton, which, after a strong heat, becomes opalescent on cooling.

It dissolves with soda into a bottle-green bead.

With the solution of cobalt it becomes black.

b. *Cologné earth*.

Alone in the matrass it gives off water, like the preceding, but the water is not alkaline. On charcoal or in the forceps it must be slowly and gradually heated, or else it flies in pieces; at a high temperature it fuses into a white glass on its thin edges.

It behaves with soda, borax and salt of phosphorus, like the preceding variety.

With the solution of cobalt it gives a blue color, which, however, is not clear.

c. *Clay* from Stourbridge, from Rouen, and from the coal-mines near Högenäs, or the so-called *fire-clays*, AS\*.

In the matrass they behave like the foregoing. Carefully heated on charcoal they lose their dark-brown color and become white. At a high temperature, they are converted on

\* This formula is computed from SEFSTRÖM's analysis of the Stourbridge and Helsingborg clay, in the "Annalen des Eisencomptoirs" for 1820.

thin edges into a slaggy, colorless glass; they do not fuse into a bead.

With borax and salt of phosphorus they behave like the preceding.

With soda they dissolve readily into a transparent glass, which is tinged with iron.

They give a pale blue color with the solution of cobalt.

*Remark.* The varieties of clay are, in general, silicates of alumina, with varying proportions of alumina, which contain water in chemical combination, as well as hygroscopic moisture. MITSCHERLICH has observed that they all contain potash, some in as large proportion as 4 per cent. The red varieties of clay contain peroxide, the blue clays the magnetic oxide of iron. The latter become red when heated in the outer flame, and black in the interior flame; with a strong heat they can be fused into a black or bottle-green glass, or they become converted into a black slag. In some the alumina is replaced by the oxide of chrome; for instance, in the varieties from Miloschin or Serbian; these give with the fluxes the reaction of chrome.

*One-third silicate of zirconia,  $\ddot{\text{Zr}} \ddot{\text{Si}}$ , (Zr S), Zircon and Hyacinth,* from Ceylon, Finbo, Fredriksvärn and Expailly.

Alone the colorless transparent variety remains unchanged. The red (hyacinth) loses its color, and becomes transparent, or very slightly yellowish. The opaque brown variety from Fredriksvärn loses its color and becomes white, resembling glass full of flaws. The dark variety from Finbo gives a little water, becomes milk-white, and appears as if it had effloresced. Neither can be fused, either when pulverized, or on the edges of the thinnest splinter.

The zircon is slowly dissolved by borax into a transparent glass, which at a certain point of saturation can be rendered opaque by flaming, and if a larger proportion of the flux be added, it becomes clouded of itself on cooling.

The zircon is not attacked by salt of phosphorus. A fragment heated in this flux retains its sharp edges, and even when pulverized it remains so unchanged, that it is impossible to decide whether it has been attacked or not. The glass remains quite colorless, or becomes milk-white when the powder is added to it, both in the oxidating and reducing flame, so that it is impossible to detect the titanium which CHEVREUL found in specimens from Ceylon, and JOHN in the Norwegian zircon.\*

\* In examining the rounded grains of hyacinth, which are known by the name of "Edelsteingrus," of which the greater portion are spinels, I found grains which resembled hyacinths, and which dissolved in the salt of phos-

It is not dissolved by soda; this flux attacks it slightly on the edges, and then sinks into the charcoal. Most varieties of zircon show the presence of manganese on platina foil.

*One-third silicate of thorina,  $\text{Th}^3\text{Si} + 3\text{H}$ , ( $\text{ThS} + \text{Aq}$ ), Thorite, from Lövön.*

In the matrass it gives off water, and becomes brownish-red. On charcoal it is infusible.

It is readily dissolved by borax; the saturated glass becomes opaque on cooling, but cannot be made so by flaming, as long as the glass remains transparent after cooling. The glass is tinged with iron.

It is dissolved by the salt of phosphorus, and leaves a siliceous skeleton. The glass is slightly tinged with iron, and becomes opalescent on cooling.

With soda, on charcoal, it forms a yellowish-brown slag. On platina the melted soda around the assay becomes green.

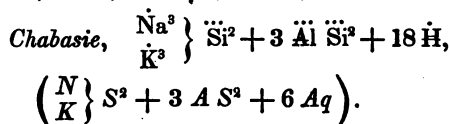
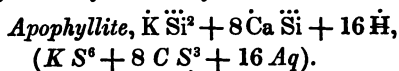
By reduction with soda, malleable globules are obtained, which indicate a small amount of lead in the mineral.

## II. SILICATES WITH SEVERAL BASES.

### A. Silicates of an alkali or alkaline earth, and silicate of alumina, united with water of crystallization.

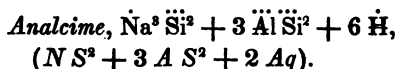
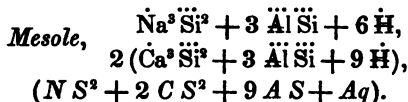
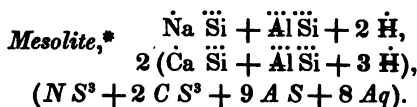
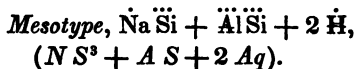
#### *Cronstedt's Zeolites.*

I have here united together these minerals, which almost all belong to the volcanic rocks, since they resemble each other so much in their behavior before the blowpipe, that they can rarely be distinguished by it. They are as follows:

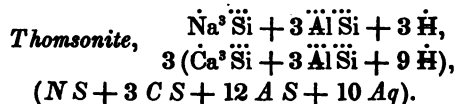


phorus, giving a faint tinge of titanium. It is possible that a mixture of these was the occasion of finding titanium in the Ceylon zircon. As to JOHN'S statement, it is evident from his own description, that what he considered titanitic acid was not so. Any one who wishes to prepare zirconia from the Ceylon mineral will do well to ignite the zircons and hyacinths, and then select the colorless grains, since those which do not lose their color are spinel, essonite, or pyrope.

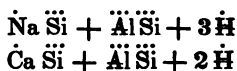
*Gmelinite* is a variety of chabasie, in which a portion of the alkalies is replaced by magnesia.



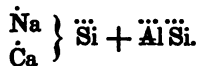
*Caporcianite* is an analcime, in which a small portion of the soda is replaced by potash and magnesia.



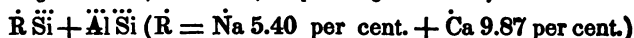
\* I prefer to arrange the formulæ in this way, since it shows that the mineral is a combination of two double salts. The sign, 2 ( ), implies that all the symbols in the following formula must be multiplied by the preceding numeral. There are several combinations of these salts, as, for instance, the *Mesolite*, of Hauenstein, which consists of



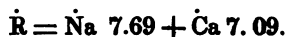
and therefore contains only one atom of each double salt, and one atom more of water in the first. Moreover, the alkalies and lime replace each other in various proportions, which cannot always be arranged according to exact proportions. In such a case it is necessary to give the formula a more general expression, e. g.

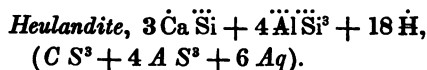
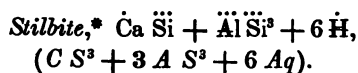


The formulæ of substitution, proposed by L. SVANBERG, deserve, in this respect, attention, since by their aid the relative proportions of the substances can be given. Thus, for instance, the preceding formula may be thus written:

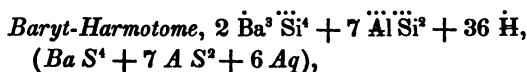
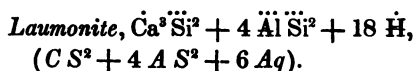


There are also varieties of mesolite in which

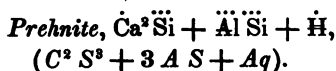
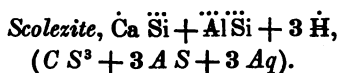
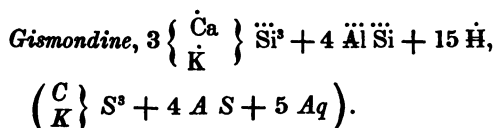
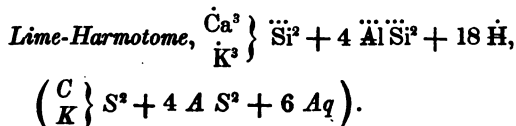




*Brewsterite.* This mineral has the same formula as the Heulandite, with the exception that  $\frac{1}{4}$  of the soda is replaced by an equivalent amount of lime.



in which a portion of the baryta is sometimes replaced by a very trifling amount of potash.



*Edingtonite* has been so imperfectly examined that a formula cannot as yet be given for it.

The general and common behavior of the zeolites is as follows: they give off a large amount of water in the matrass; the greater portion of them become opaque and milk-white.

On charcoal they swell and intumesce. This intumescence, which gave a name to the family of Zeolites (from *τεω*, I boil),

\* *Epistilbite* is the same combination, with only 5 atoms of water, and in which a small portion of lime is replaced by soda, which is also the case in Haüy's *Stilbite dodecaédre lamellaire*.

seems to be of the same nature as the crumbling of arragonite, and the loss of transparency of bitter spar when heated to + 50° centigrade, which is due to a change in the relative position of the particles, and not to the escape of any volatile substance.—They afterwards fuse to a colorless glass, which is transparent, though it appears milk-white from the number of bubbles which it encloses.

They are readily dissolved by borax into a colorless glass.

They are decomposed by salt of phosphorus. The silica swells up in the bead, remains transparent, and sometimes absorbs nearly the whole of the flux.

With soda they fuse to a transparent glass.

Some of the zeolites exhibit peculiar phenomena, which may serve to distinguish them from each other.

*Apophyllite* swells up in the direction of the foliated cleavage. Its saturated solution in borax can be rendered opaque and milk-white by flaming. In the open tube it gives the reaction of fluoric acid.

*Mesotype* becomes opaque, if large crystals are employed, and fuses without intumescence. The acicular crystals swell in the direction of their length, a circumstance from which it may be inferred that it contains a mixture of mesolite.

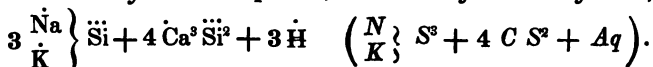
*Analcime* becomes at first milk-white as it loses its water, and afterwards fuses at a higher temperature, without intumescence.

*Laumonite* begins to intumesce when merely kept exposed to the air, when it swells up and crumbles to powder, but this is not occasioned by the loss of water. When fused, the glass is first enamel-white, but if remelted at a higher temperature it becomes transparent.

*Prehnite* does not lose its transparency in losing its water. *Koupholite*, a variety of the same, which often contains dust from the way in which it is found, blackens and emits a burnt odor; the carbon can be entirely burnt away without destroying the transparency of the mineral. They both intumesce, and give a glass with soda with considerable difficulty.

*Baryt-harmotome* fuses without previous intumescence. With a small quantity of soda, it gives a transparent glass; with a larger portion, the glass becomes opaque on cooling, and can be rendered milk-white by flaming.

*Silicate of soda and potash, with one-half silicate of lime,*



*Pectolite*, from Monte Baldo.



This mineral generally contains weathered portions which are united to the transparent mineral.

a. *Transparent portion.*

Alone in the matrass it gives off water, loses its transparency, and crumbles, when gently touched, into acicular fragments.

In the forceps it fuses quietly into a transparent glass without intumescence.

With borax it gradually dissolves into a transparent glass.

With the salt of phosphorus it gives a siliceous skeleton, and an opalescent glass.

With soda it swells up like a zeolite, and fuses into a blebby, colorless slag.

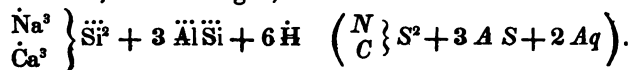
With the solution of cobalt it acquires a blue color, bordering on purple, even before fusing.

b. *Weathered portion.*

It gives off a large quantity of water in the matrass. It does not fuse on charcoal or in the forceps. It gives with soda a transparent glass. With cobalt it gives a purple-blue color, and resembles, in other respects, the transparent portion in its behavior.

*Two-thirds silicate of soda and lime, with one-third silicate of alumina.*

*Brevicite*, from Brewigen,



In the matrass it gives off a large quantity of water, but changes its appearance very little.

In the forceps and on charcoal it melts into a colorless blebby glass.

It is readily dissolved by borax into a transparent glass.

It is decomposed and leaves a siliceous skeleton with the salt of phosphorus, giving an opalescent glass.

With soda it does not form a glass, but gives a white slag; on platina it does not color the soda.

B. *Silicates of alkalis or alkaline earths, combined with silicates of alumina, without chemically combined water.*

*Supersilicates of an alkali and alumina.*



from Baulabjerg, Iceland.

Alone in the matrass it gives a small quantity of moisture.

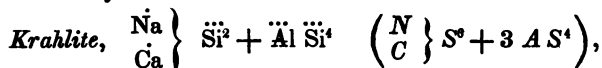
Strongly ignited in the forceps, it is at first transparent and resembles ice, but afterwards fuses at the point to a transparent, colorless glass, but cannot be melted to a bead, unless the splinter is very small.

It is very slowly dissolved by borax. If previously pulverized it is readily attacked. The glass is transparent and colorless.

In the salt of phosphorus it dissolves very slowly, but when pulverized it is decomposed, and a siliceous skeleton is separated, which fills the bead, so that it is no longer liquid. This can be dissolved, however, by the addition of a large portion of the salt of phosphorus. The glass is transparent and colorless, but becomes opalescent on cooling.

With soda it fuses with effervescence into a transparent, colorless glass.

With the solution of cobalt it becomes black, and the fused portions only are blue.



from Kraftinnahruggr, Iceland.

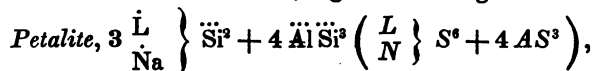
Alone in the matrass it gives rather more water than the preceding, but does not lose its reddish-grey color on cooling.

In the forceps it acquires an icy appearance, and fuses at the point to a transparent, colorless glass. The portion which resembles ice is mingled with transparent, brownish portions.

With borax and salt of phosphorus it behaves exactly like the preceding.

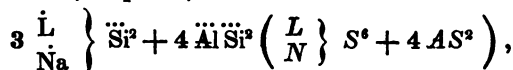
It dissolves with soda, and gives a bottle-green glass.

With the solution of cobalt, it gives a black glass.



from Utön, behaves exactly like feldspar; but, when finely pulverized, if mixed with the bisulphate of potash and fluor spar, and fused on platina foil, it tinges the flame red, around and before the assay.

*Spodumene, Triphane,*



from Utön and Tyrol.

Alone in the matrass it is deprived of its water, and becomes white, and less transparent than before. On charcoal,

it intumesces like the double silicates of lime and alumina, and afterwards fuses to an almost transparent and colorless glass.

With borax, it also puffs up, but is not readily dissolved; the swollen mass becomes transparent and rounded, but remains for a long time without dissolving.

In the salt of phosphorus, it swells in the same way, but is tolerably readily dissolved, leaving a siliceous skeleton.

With soda, it intumesces, and is afterwards dissolved to a transparent glass, which becomes opaque on the addition of more soda, but does not become less fusible.

With the solution of cobalt, it gives a blue glass.

With the bisulphate of potash and fluor spar, it behaves like petalite.

*Neutral silicate of alumina and potash*,  $K\ddot{S}i + \ddot{A}l\ddot{S}i^3 (KS^3 + 3AS^3)$ , *Feldspar*.

Alone in the matrass the transparent varieties do not give off water. The splintered and weathered specimens often give off a considerable quantity, which was mechanically included in the fissures. On charcoal, it becomes in a strong heat glassy, semi-transparent, and white, and fuses with difficulty on the edges to a semi-transparent, blebby glass. It is exceedingly difficult to fuse it.

It is very slowly dissolved by borax, without effervescence, into a transparent glass.

Salt of phosphorus attacks it very slightly. Pulverized, it is decomposed, and leaves a siliceous skeleton, and the bead becomes opalescent on cooling.

It is slowly dissolved by soda with effervescence into a transparent and exceedingly infusible glass, which can be rarely obtained free from bubbles.

With the solution of cobalt it becomes blue, but only on the fused edges.

TURNER observes that he obtained from several varieties of feldspar, by the use of bisulphate of potash and fluor spar, a flame tinged with green, indicating the presence of boracic acid.

*Neutral silicate of alumina and soda*,  $Na\ddot{S}i + \ddot{A}l\ddot{S}i^3 (NS^3 + 3AS^3)$ , *Albite*, behaves like feldspar.

Albite and feldspar can, however, be distinguished from each other by the blowpipe, if they be dissolved in glass of borax, in which oxide of nickel has been previously dissolved. Feldspar colors the bead blue, or dark purple; with albite, on the contrary, it retains its original brown color. It must be observed, however, that a very trifling proportion of potash in the albite causes it to give the same reaction as feldspar.

*Neutral silicate of soda with two-thirds silicate of alumina*,  $\text{Na} \ddot{\text{Si}} + \ddot{\text{Al}} \ddot{\text{Si}}^2$ , ( $\text{NS}^3 + 3 \text{AS}^2$ ), *Soda-spodumene*, from the granite around Stockholm (the soda is partially replaced by potash, lime, and magnesia); it behaves like feldspar, but fuses so much more readily into a transparent glass, that this circumstance alone is sufficient to distinguish the two from each other.

*Two-thirds silicate of alumina and potash*,  $\text{K}^3 \ddot{\text{Si}}^3 + 3 \ddot{\text{Al}} \ddot{\text{Si}}^3$  ( $\text{KS}^2 + 3 \text{AS}^2$ ), *Leucite*, *Amphigène*.

Alone in the matrass it does not give off water. On charcoal, it undergoes no change, and does not fuse, even when pulverized. If the powder be mingled with a very small quantity of carbonate of lime, it shows distinct signs of fusion.

It is dissolved by borax slowly, but in large quantity, into a transparent glass.

It is very little attacked by salt of phosphorus, either in fragments or pulverized; but it becomes transparent in the bead, and has the same degree of refraction, so that it is almost impossible to distinguish the undissolved portion. It can be observed, however, when an attempt is made to flatten the melted bead against a hard substance.

With soda it dissolves slowly with effervescence to a transparent, but blebby glass.

With the solution of cobalt it gives a fine blue, without fusing.

*Neutral silicate of soda and lime, with one-third silicate of*

*alumina*,  $\text{Na} \ddot{\text{Si}} + \ddot{\text{Al}} \ddot{\text{Si}}^2$  ( $\text{NS}^3 + 3 \text{CS}^3 + 12 \text{AS}$ ),  
 $3 (\text{Ca} \ddot{\text{Si}} + \ddot{\text{Al}} \ddot{\text{Si}}^2)$

*Labradorite*, from Labrador, behaves exactly like feldspar, and even gives a blue bead with the oxide of nickel and borax.

*Two-thirds silicate of soda and lime, with one-third silicate*

*of alumina*,  $\left. \begin{array}{c} \text{Ca}^3 \\ \text{Na}^3 \end{array} \right\} \ddot{\text{Si}}^3 + 2 \ddot{\text{Al}} \ddot{\text{Si}}^2 \left( \frac{\text{C}}{\text{N}} \right\} \text{S}^2 + 2 \text{AS} \right)$ ,

*Wernerite*, *Paranthine*, *Scapolite*.

a. *Meionite*, from Vesuvius.

Alone in thin splinters it gives off bubbles at certain points, which cause the whole mass to boil and foam violently for a long time. It gives a transparent, blebby glass.

It is dissolved by borax slowly with continuous effervescence into a transparent glass.

It is decomposed by the salt of phosphorus with effervescence, gives a siliceous skeleton, and becomes opalescent on cooling.

It is slowly dissolved by soda, with strong intumescence, into a transparent glass. It requires a large quantity of soda, and remains for a long time opaque on the edges.

With the solution of cobalt it gives a blue color, but only on the fused edges.

b. *Wernerite*, from Pargas.

Alone in the matrass it gives off a small quantity of water, but does not lose its transparency. On charcoal it undergoes no change at a moderately red heat; but at a higher temperature it fuses and swells up; after this it forms a colorless, uneven, opaque mass, looking like ice, and becomes infusible.

With borax it dissolves with continuous effervescence into a transparent glass. This continues to effervesce, even after it has been so long fused that it has ceased to intumesce.

Salt of phosphorus decomposes it in the same way, with effervescence.

With soda it fuses slowly to a transparent glass, which becomes still more infusible if more soda be added.

With the solution of cobalt it gives a blue glass.

c. *Wernerite*, from Malsjö.

Alone it becomes milk-white before it begins to fuse, and afterwards melts to a colorless glass, which is rendered opaque by bubbles. In the open tube it gives the reaction of fluoric acid.

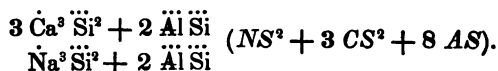
Borax and salt of phosphorus decompose it with effervescence, as they do the preceding.

With soda it fuses very readily into a transparent glass, which does not swell up or become infusible on the addition of a farther quantity.

d. *Wernerite*, from Arendal (Paranthine vitreux— $\text{H}_2\text{U}_2\text{Y}$ ), behaves exactly like the preceding.

e. *Dipyre*, from Mauleon, behaves exactly like the *Wernerite* from Malsjö. It gives off, like the others, a small quantity of water, without losing its transparency, and seems, in spite of VAUQUELIN'S analysis, to be a scapolite.

f. *Ekebergite*, from Hesselkulla and Pargas.



Alone in the matrass it gives off a little water, but does not change its appearance. On charcoal it becomes white and opaque, puffs up a little, and afterwards fuses into a colorless, blebby glass.

It dissolves like scapolite with borax and salt of phosphorus, with effervescence.

It fuses, like the scapolite from Pargas, with soda, with great difficulty, into a transparent, greenish glass.

*Two-thirds silicate of soda with one-third silicate of alumina*,  $\text{Na}^3\ddot{\text{Si}}^2 + 2\ddot{\text{Al}}\ddot{\text{Si}}$ , ( $N S^2 + 2 A S$ ), *Sodalite*, from Vesuvius, where it occurs with garnet; \* it is contaminated with hydrochloric acid.

In the matrass it does not change, and does not give off water.

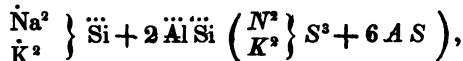
On charcoal it does not lose its transparency, and fuses less readily than Wernerite but more so than feldspar, into a blebby glass.

It is dissolved slowly and without effervescence by borax, into a transparent glass. The assay divides itself through the flux, the undissolved portion resembling a siliceous skeleton.

It is slowly dissolved by the salt of phosphorus, but the undissolved portion does not divide itself in the flux.

It fuses slowly into a blebby glass with soda.

*One-third silicate of alumina, potash and soda*,



*Elaeolite*. The potash and soda often replace each other in such large proportion that the following species have been formed.

a. *Elaeolite*, from Fredriksvärn.

Alone in the matrass it gives off water, but does not change its appearance, or lose the degree of transparency which it had at first.

On charcoal it fuses with considerable facility, and slight intumescence, into a colorless, blebby glass.

It is dissolved by borax, like mesotype, at first readily, but it leaves a semi-transparent substance, which requires to be heated for a long time before it disappears.

It is dissolved by the salt of phosphorus with great difficulty, and leaves a siliceous skeleton. The glass is opalescent on cooling.

With soda it gives a glass with the greatest difficulty, which is scarcely fusible, and which it is difficult to obtain clear.

With the solution of cobalt it becomes blue on the fused edges.

b. *Nepheline*, from Vesuvius.

Alone on charcoal it becomes rounded on the edges, but

\* TROLLE-WACHTMEISTER, in POGGENDORFF'S ANNALS, II. p. 14.

does not appear to intumesce at all. It cannot be perfectly fused into a bead, but it gives a colorless, blebby glass.

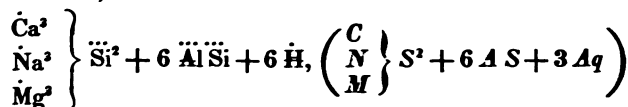
It is dissolved by borax slowly and without effervescence, into a transparent, colorless glass.

It is dissolved by salt of phosphorus without hissing, and leaves a siliceous skeleton. The bead becomes opalescent on cooling.

With soda it first swells up, and then dissolves into a transparent, blebby glass.

The solution of cobalt gives to the unmelted mass of the powder a greyish-green color, and to the fused edges a greyish-blue.

*One-half silicate of potash and lime, with one-third silicate of alumina,*



*Rosite*, from the lime quarry at Åker.

Alone in the matrass it gives off water, its red color disappears, and it becomes colorless.

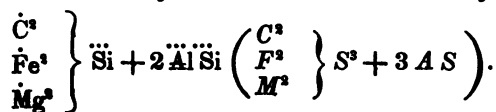
Heated in the forceps it does not swell up, and does not fuse, except in very thin splinters, when it fuses to a white slag.

In borax it dissolves with effervescence, the glass is colorless and transparent.

It is very slowly dissolved by salt of phosphorus. The undissolved substance becomes rounded and milk-white. Pulverized it gives a siliceous skeleton.

With soda it forms gradually a transparent, colorless glass, which does not become infusible or slaggy by the addition of more soda, which distinguishes it from the next mineral, which it very closely resembles. On platina foil it gives a weak but distinct color of manganese.

*Two-thirds silicate of lime, with one-third silicate of alumina,*



*Amphodelite*, from various primitive lime beds.

It gives in the matrass water, without changing its appearance.

On charcoal it becomes milk-white at a white heat, and then

fuses, without intumescence, and slowly, into a colorless, blebby glass, which cannot be melted into a bead.

Borax dissolves it slowly and without effervescence to a transparent glass, for which, however, a large quantity of the flux is requisite.

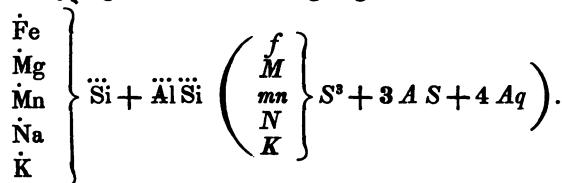
Salt of phosphorus dissolves it exceedingly slowly. It does not swell up, but becomes rounded on the edges, and milk-white.

The powder is easily decomposed, gives a siliceous skeleton, and a transparent, colorless, opalescent glass.

With soda a white slag is obtained, which is not liquid even with a smaller quantity of the flux.

With the solution of cobalt a fine blue color is obtained.

*Neutral silicate of magnesia, protoxide of iron, protoxide of manganese, potash and soda, with one-third silicate of alumina. Pyrgillite, from Helsingborg.*



It gives off a large quantity of water in the matrass, without changing its appearance.

It is infusible, but becomes somewhat glassy in the strongest possible heat. The assay then appears to be covered with a greyish-white, ruptured crust.

Borax dissolves it very slowly. The undissolved portion remains whitish-grey, and cracked upon the surface. The glass is colored with iron, but its color disappears on cooling.

It behaves in the same way with the salt of phosphorus.

With soda it swells up and forms a grey slag, which has a greenish hue as long as it remains warm. It does not give a green color on platina.

*Neutral silicate of lime, with two-thirds silicate of alumina,  $\text{Ca} \ddot{\text{Si}} + \ddot{\text{Al}} \ddot{\text{Si}}^2 (C S^2 + 3 A S^2)$ , Lime-oligoclase, (Havnefjordit,) from Havnefjord, Iceland.*

Alone in the matrass it gives a slight trace of moisture.

In the forceps it melts at a high temperature, and gives a transparent, colorless, somewhat opalescent glass.

It dissolves with borax slowly, but, if pulverized, readily, into a transparent glass.

It is rather more readily dissolved by the salt of phosphorus. If pulverized it gives a swollen siliceous skeleton.





that all varieties of mica contained more or less distinct traces of fluoric acid, with a small amount of water. But even these analyses fail to give us a correct idea of the chemical formula of mica. ROSE's analyses would give the formula  $\text{K}^{\text{S}} + 12 \text{A}^{\text{S}}$ , in which one or more atoms of silicate of alumina are replaced by silicate of iron or manganese, provided the bases existed in the state of peroxides. But in the course of the experiments which he instituted to ascertain this point, he found that ferriferous mica, when ignited in a retort, became green, and acted on the magnet, without having given off any gas from which the deoxidation of the supposed peroxide might be inferred.

The different polarization of light in different varieties of this mineral adds to the uncertainty, as well as the remarkable fact mentioned by BIOR, that a certain very magnesian mica has only one axis, while this mineral generally has two.

In regard to the behavior of the varieties of mica at a high temperature, ROSE found that those which contain from one-half to one per cent. of fluoric acid, when heated in closed vessels lose their lustre and become dull. The other varieties, on the contrary, maintain their semi-metallic lustre, and only change their color. The loss of lustre in the micas containing fluoric acid is evidently owing to the decomposition which takes place on the surface of the scales as the fluoric acid escapes, taking with it the silica to form fluosilicic acid.

It follows from this that the behavior of mica varies with its locality, like the garnet, and that it is impossible to give a characteristic blowpipe test for all the varieties of this mineral. I shall on this account only select a few varieties for description.

a. *Mica*, from Broddbo and Finbo, in granite.

Alone in the matrass it gives off water, which gives evident traces of fluoric acid when the heat is raised to the melting point of glass. The mica treated in this way becomes green, loses its lustre, and becomes rough to the touch on its surface. Heated in the flame before the blowpipe it becomes white, or whitish-grey, but retains its lustre, becoming rough upon the surface by swelling up. On the edges it cracks in the direction of the folia, and fuses into a greyish-yellow, blebby glass.

It is readily dissolved by borax with effervescence into an iron-green glass. The mineral which had been ignited in the matrass dissolves without effervescence.

It is readily decomposed by the salt of phosphorus, and swells up into a siliceous skeleton, which would hardly be noticed, were it not that it alters the shape of the bead. If a

small proportion of mica be employed, the skeleton can be dissolved by skilful blowing; but if more be added, the greater portion remains undissolved. The bead becomes opalescent on cooling.

With soda it swells up, at first, into a green, then into a grey slag, in which only that side upon which the flame was directed is fused into a transparent, somewhat greenish glass. It gives distinct traces of manganese on platina foil.

With the solution of cobalt it gives a black glass.

b. *Mica*, from North America, in granite.

Alone in the matrass it gives off water, without becoming opaque. At the melting-point of glass it becomes white, and acquires a silvery lustre. It gives slight traces of fluoric acid. On charcoal it becomes milk-white, and afterwards fuses, at a very high temperature, into a white enamel, but only on the extreme edges; even the thinnest scale cannot be fused into a bead.

It is dissolved by borax, at first with gentle effervescence, but afterwards quietly; if the mineral had been previously ignited till it became opaque, it dissolves without effervescence.

It is at first entirely dissolved by the salt of phosphorus, if not too large a quantity is employed. Afterwards it is slowly decomposed, and leaves a siliceous skeleton. The glass becomes opalescent, but not till after having been long heated.

With soda it gives a white slag, which fuses to a transparent glass on the edges exposed to the direct action of the flame.

With the solution of cobalt it becomes blue on the fused edges.

c. *Mica*, from the Pargas lime quarry, a fragment of a six-sided prism.

Alone in the matrass it gives off water, without changing its appearance; at a higher temperature it gives no trace of fluoric acid. It does not lose its smoky-brown color, even when ignited in the flame. It fuses readily to a milk-white glass, which can be obtained in the form of a bead. The unmelted portion of the mica preserves its perfect transparency, at the point where the fused portion ends.

It is dissolved by borax quietly and without effervescence. The scale of mica remains quite transparent, and gradually diminishes in size, till it finally disappears.

It is readily dissolved by the salt of phosphorus, leaving a perfectly transparent siliceous skeleton. The glass is opalescent.

With soda it swells up, becomes milk-white, and fuses into an opaque bead, which becomes milk-white on cooling.

With the solution of cobalt it becomes light blue on the fused edges.

*Remark.* If the external characters did not show that these three minerals were all micas, it would hardly be inferred from their behavior before the blowpipe, that they all belonged to the same class of minerals. The fusibility of the Pargas mica and the infusibility of the American variety, imply a considerable difference of composition. This difference resembles that which distinguishes common schorl from the tourmaline apyre, of which two varieties the composition is quite different.

*Lepidolite*, or *Lithia mica*, from Utön.

Alone in the matrass it gives off water, which, if the assay is raised to a red heat, is rendered quite acid by fluoric acid, and tinges Brazil-wood paper yellow; the glass becomes clouded in spots from the deposition of silica. On charcoal it fuses very readily with intumescence into a blebby, transparent, colorless glass.

It dissolves with borax readily and in large quantity into a transparent glass.

With salt of phosphorus it dissolves, leaving a siliceous skeleton. The bead becomes opalescent on cooling.

With soda it fuses readily with intumescence into a transparent and somewhat blebby glass.

With the solution of cobalt it becomes blue on fusing.

With boracic acid and iron it does not give a phosphuret of iron. With bisulphate of potash, or sulphate of ammonia and fluor-spar, it tinges the flame before and around the assay red, thus proving that it contains lithia.

#### *Varieties of talc.*

What I have said of mica may be applied with justice to talc, of which a few examples may serve as proof.

a. *Transparent, green talc*, from la Vallée de Bine.

Alone it gives off no water, neither does it lose its transparency when ignited. At a high temperature it exfoliates, and becomes white where the heat is most intense, but does not fuse.

Borax dissolves it readily with strong effervescence into a transparent glass.

It is easily decomposed by the salt of phosphorus, with effervescence; it gives a translucent siliceous skeleton, and an opalescent glass.

With soda it intumesces, and gives a white semi-fused slag.

With the solution of cobalt it gives a pale red color.

b. *White, opaque talc*, from la Vallée de Fenestrolle, behaves like the preceding variety, but does not effervesce so strongly when treated with the fluxes.

c. *Greenish, translucent talc*, from Skyttgrufva, near Fahlun.

Alone in the matrass it gives no trace of water; it emits a little light on the edges, but remains transparent at a gentle heat. More strongly heated, it whitens, becomes scaly on the surface, and fuses on the edges to a white, blebby mass.

It dissolves with borax, with effervescence, into a transparent glass, which has the characteristic color of iron, as long as it remains hot. A portion remains undissolved, which afterwards slowly dissolves, without effervescence.

With soda it swells up and fuses into an opaque, difficultly liquefiable glass, which may be rendered transparent by the addition of a certain proportion of soda. In general a large proportion of this flux is required.

Strongly heated with the solution of cobalt it acquires a reddish color.

*Remark.* All the varieties of talc from the Fahlun mines behave in the same way.

d. *Black talc*, from Finbo, near Fahlun.

Alone in the matrass it gives off a large amount of water, which shows, after the assay has been heated to ignition, distinct traces of fluoric acid. By ignition it acquires a lighter shade of color, bordering on green, and afterwards fuses tolerably readily to a black glass.

It is readily dissolved by borax, without much effervescence, and gives a glass tinged with iron.

It is also readily decomposed by the salt of phosphorus, and gives a siliceous skeleton; the glass is tinged with iron as long as it remains hot, but becomes opalescent on cooling.

With a certain proportion of soda it fuses to a black glass, which becomes less fusible, and acquires a yellowish-brown color, if more of the flux be added.

On platina foil it exhibits traces of manganese.

*Addition.* *Pimelite*, nickeliferous talc, from Kosemütz.

Alone in the matrass it blackens and gives off water, which smells of petroleum. The black color comes from carbon, which consumes in the open atmosphere; after which the mass becomes greyish-green, bordering on brown. It does not fuse, but becomes slaggy on its thin edges, and acquires a dark grey color.

With borax it dissolves with the reaction of the oxide of nickel, and does not give a trace of cobalt after the reduction of the nickel.

It is dissolved by the salt of phosphorus, when a small quantity of the assay is used, into a transparent glass. If more of the assay be added, a glass tinged with nickel is obtained, and an undissolved siliceous skeleton remains in the bead.

Soda dissolves it imperfectly into a rounded, slaggy mass, and after washing the charcoal a large quantity of reduced nickel is obtained.

*Remark.* Pimelite has exactly the appearance of a nickeliferous talc. The property of blackening when heated in a closed vessel and giving off an empyreumatic odor, is so far common to minerals containing magnesia, that I have rarely failed to detect it, in case the magnesia formed a constituent part of the mineral, or was contained in it in considerable quantity. These circumstances require that the pimelite should be more carefully examined. It is not improbable that the oxide of nickel may have similar properties with magnesia, exactly as it resembles the latter in its double salts with ammonia and potash.

*Chlorite*, from Fahlun.

Alone in the matrass it gives off water, and, at the melting point of glass, fluoric acid, which tinges Brazil-wood paper yellow, and leaves silica upon the glass. On charcoal it fuses into a black bead with a dull surface.

With borax it dissolves into a dark green glass.

Salt of phosphorus dissolves it, leaving silica. The glass is strongly colored with iron.

Soda does not dissolve it; it does not swell up, but becomes rounded on the edges. On platina it exhibits no traces of manganese.

*Pinite*, from St. Pardou in Auvergne, and from Greenland.\*

Alone in the matrass it gives off a little water, but does not change its appearance. On charcoal it becomes white, and fuses on the edges into a white, blebby glass. On the specimens from Auvergne colored spots are seen scattered over the surface. The ferriferous variety sometimes melts readily into a black glass.

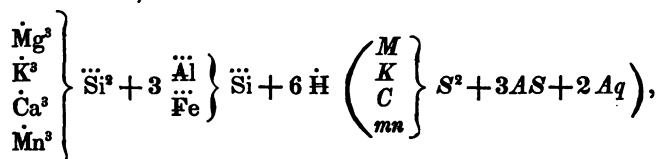
It is very slowly dissolved by borax, even when pulverized, and gives a transparent glass, which is slightly tinged with iron.

The variety from Auvergne is not visibly attacked, if the mineral is used in fragments; but the bead has a tinge of iron

\* The latter specimen was obligingly furnished me by M. Haüy. It is crystallized in six-sided prisms, and is purer and less mixed with foreign matters than most specimens.

as long as it remains hot. In powder, it can be decomposed after long blowing, and leaves a siliceous skeleton. The glass is opalescent on cooling. The Greenland variety is more easily dissolved by the salt of phosphorus, but the glasses are, otherwise, alike.

*Fahlunite,*



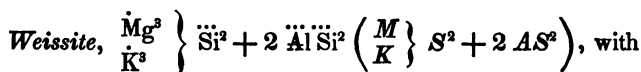
from Eric Matts mine, at Fahlun.

Alone in the matrass it gives off water, which has not an acid reaction. On charcoal it burns white, and fuses on the edges into a white, blebby glass.

With borax it is dissolved, with great difficulty, into a glass which is somewhat colored by iron.

Salt of phosphorus decomposes it, leaving a siliceous skeleton; the glass is opaque, and has a tinge of iron as long as it remains hot; but on cooling it becomes colorless and opalescent.

It is not dissolved by soda, but acquires a slaggy appearance, and a yellowish color.



traces of soda, manganese, and tin, from Eric Matts mine, at Fahlun.

Alone in the matrass it gives off water, which has at first an acid, afterwards an alkaline, reaction. Its color grows darker.

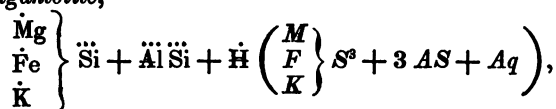
On charcoal it becomes milk-white, and afterwards fuses on the edges, but cannot be entirely liquefied. After a strong heating in the reducing flame, the charcoal becomes coated with a deposit of the oxide of tin.

With borax it dissolves gradually, giving a transparent, colorless glass.

With salt of phosphorus it is very slowly dissolved, leaving a siliceous skeleton. The pulverized mineral is rapidly taken up, and swells up into a siliceous skeleton.

With soda it gives a white slag, which, in a strong heat, can be melted into a bead. On platina foil it gives no distinguishable trace of manganese.

*Gigantolite*,



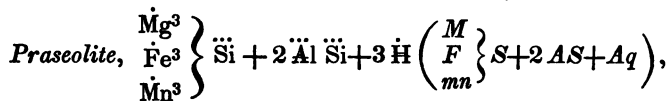
from Tammela, Finland.

Alone in the matrass it gives off water, which at length acquires an alkaline reaction.

It fuses readily, with intumescence, into a lustrous, greenish slag, but cannot be melted into a bead.

In borax and salt of phosphorus it dissolves into a transparent glass, which is tinged with iron, but becomes colorless after it has cooled. The solution proceeds slowly unless the mineral be pulverized, when it swells into a siliceous skeleton with the salt of phosphorus, and dissolves completely in a larger quantity of the flux. The transparent glass becomes opalescent on cooling.

With soda it swells into a brown slag, which can be made to take a globular shape with considerable difficulty.



(containing, at the same time, traces of the oxides of manganese, lead, copper, cobalt and titanium,) from Bråkke, in Bamla parish, Norway.

Alone in the matrass it gives off water, which has no effect on Brazil-wood paper. The clear-green assay becomes dirty-green, and partially brownish.

In the forceps it fuses slowly, and only on the edges into a bluish-green glass.

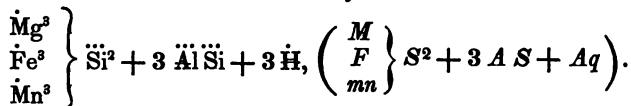
It is dissolved by borax into a transparent, greenish glass.

In the salt of phosphorus it is less easily dissolved, and leaves a siliceous skeleton. In a strong reducing flame, or with the help of tin, the presence of titanium can be observed, though only faintly.

With soda it forms a pea-green slag, bordering on yellow.

With the solution of cobalt a greyish-blue color is obtained.

*Esmarkite*, from the same locality.



Behaves exactly like the preceding.



D. *Silicates of an alkali and oxide of iron.*

*Neutral silicate of soda, with two-thirds silicate of the peroxide of iron.* *Acmite*,  $3 \text{Na} \ddot{\text{Si}} + 2 \ddot{\text{Fe}} \ddot{\text{Si}}^3 (N S^3 + 2 F S^2)$ , from Eger in Norway.

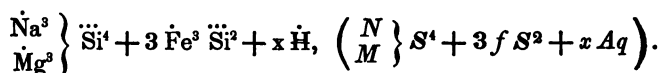
Alone in the matrass it gives off water, which on drying leaves a stain upon the glass, which disappears when heated. The appearance of the assay remains unchanged. On charcoal it fuses to a black bead with a vitreous lustre.

It is readily dissolved by borax into a glass tinged with iron.

With salt of phosphorus its behavior is the same, except that a siliceous skeleton remains.

With soda on charcoal it gives a black glass, and on platina the usual reaction of manganese.

*Persilicate of soda and magnesia, with one-half silicate of the protoxide of iron.* *Crocidolite*, from Orange River, Cape of Good Hope.



Alone in the matrass it gives off a small amount of water, having an empyreumatic odor, and becomes brown.

A fibre of the mineral bends upon itself in the flame, and forms a brownish slaggy mass, which cannot be fused into a bead without considerable effort.

The fibre is immediately taken up by borax, dissolves with effervescence, and colors the bead with the oxide of iron.

It is readily dissolved by salt of phosphorus, leaving a siliceous skeleton. On the platina wire the glass, treated in the oxidating flame, is red as long as it remains hot, but it becomes colorless on cooling. It splits in pieces and then exhibits amethystine-red patches in the interior of the siliceous skeleton, which appearance cannot be produced on charcoal.

Saltpetre does not show the presence of manganese, or tin that of titanium.

With soda it gives on platina a red glass, which does not exhibit the reaction of manganese; on charcoal it gives a greyish green glass.

*E. Silicates of lime and magnesia, in which the alkaline earths are more or less fully replaced by protoxide of iron and protoxide of manganese, and the silica sometimes replaced by alumina.*

*Neutral silicate of lime, with two-thirds silicate of magnesia.*

*Amphibole,  $\text{Ca Si} + \text{Mg}^3 \text{Si}^2$ , ( $\text{C S}^2 + 3 \text{M S}^2$ ).*

VON BONSDORFF has shown that all the varieties of amphibole contain fluoric acid, which is united to the lime, forming fluoride of calcium, and that they can be considered as thus composed: 1 atom of the fluoride of calcium is combined with an amount of the above-named combination, which contains 5 times as much lime as the fluoride of calcium. It is possible that the correct formula is  $\text{Ca Fl}^2 + 5 (\text{Ca Si} + \text{Mg}^3 \text{Si}^2)$ , in which case this mineral should be included among the halogen substances. The presence of the fluoric acid cannot be ascertained by the blowpipe.

*a. Non-aluminiferous amphibole.*

*a. Colorless amphibole*, from Gullsjö in Wermland, has exactly the composition represented by the above formula.

Alone in the matrass it does not change, and gives off only hygrometric water. In the forceps it fuses readily with intumescence into a semi-transparent glass, and the portion nearest the fused mineral becomes milk-white. Each time that the mineral is remelted it begins by swelling up, but afterwards liquefies.

It is slowly dissolved by borax into a transparent, colorless glass.

It is not decomposed by the salt of phosphorus; the fragment remains in the bead rounded on the edges and quite milk-white in color, and if it be heated for a long time the glass becomes opalescent on cooling.\*

With a certain portion of soda it dissolves into a transparent glass, which swells up on the addition of more soda, and forms a white, infusible, slaggy mass.

With the solution of cobalt it acquires a rose-red color on the fused edges.

*β. Grammatite*, from Fahlun.

\* This property belongs to the amphiboles in common, with few exceptions. There is, however, a method of decomposing them with salt of phosphorus, which often succeeds, namely, by melting them with so small an amount of this flux that the surface only is covered. When the assay begins to swell up, the phosphoric acid penetrates the mass, which intumescs, is decomposed, and becomes icy in appearance.

Alone it undergoes no change when gently ignited. At a higher temperature it swells up, cracks longitudinally, and becomes milk-white; at a still higher temperature it fuses with effervescence into a whitish-grey, rough, opaque mass.

With borax and salt of phosphorus it behaves like the preceding mineral.

With a suitable quantity of soda it fuses to a transparent glass; with too much or too little the glass becomes opaque on cooling.

With solution of cobalt it becomes dark red on the fused edges, and clear bright red around the assay.

γ. *Asbestiform tremolite*, from Sheffield, Massachusetts.

Alone it bubbles and fuses with difficulty into a vitreous mass, after which fine acicular crystals often shoot out.

With borax and salt of phosphorus it behaves like the preceding.

With soda it is dissolved with the greatest ease into a transparent glass, which must be fused with a large quantity of the flux before it becomes opaque.

With the solution of cobalt it reddens on the fused edges.

δ. *Asbestus*, from the Tarentaise,  $(CS^2 + 3 \frac{M}{f} S^2)$ .

Alone it fuses readily into a greyish bead resembling enamel, but without a vitreous surface.

With the fluxes it behaves like α.

ε. *Asbestiform actinolite*, from Taberg near Philipstad, and from Fahlun, has the same formula as the preceding.

It is not particularly changed in appearance by gentle ignition. In a strong heat it becomes white, and then fuses with intumescence into an opaque, dark yellowish glass.

It fuses readily with borax to a transparent glass, tinged with iron.

It is very slightly acted on by the salt of phosphorus. The acicular crystals remain unchanged, and the glass becomes opalescent on cooling.

With a small proportion of soda it gives an opaque, greenish glass; with a larger quantity it swells into an infusible slag.

With the solution of cobalt it becomes red on the fused edges.

*Remark.* The greener varieties of actinolite give to the glass a deeper color of iron, but their behavior is, otherwise, the same.

ζ. *Byssolite*, from Bourg de l'Oisons, has the same formula as δ.

Alone it fuses into a black, brilliant bead.

It is readily dissolved by borax into a glass colored with iron. Salt of phosphorus dissolves it slowly; the acicular crystals which are first added to the flux dissolve entirely, the others remain undissolved.

With soda it gives a black glass; with a larger quantity, a black slag. On platina foil it exhibits the reaction of manganese.

b. *Aluminiferous amphibole.*

7. *Grammatite*, from Åkers lime quarry. The empiric formula for this and the following varieties is, rejecting the

fluoric acid,  $\text{Ca} \ddot{\text{Si}} + \begin{matrix} \text{Mg}^3 \\ \text{Fe}^3 \end{matrix} \left\{ \begin{matrix} \ddot{\text{Si}}^3 \\ \ddot{\text{Al}}^3 \end{matrix} \right\}$  and, in general, to 5 atoms

of this combination, 1 atom of fluoride of calcium. Other varieties contain also protoxide of manganese.

Strongly ignited it becomes white without splitting, and fuses considerably easier than the grammatite from Fahlun, and much like that from Gullsjö, and gives an almost transparent glass.

It dissolves readily with borax to a transparent glass.

With the salt of phosphorus it swells up, is not entirely decomposed, but is converted into a translucent, light colored mass, which, however, remains hard internally.

With soda it fuses to an opaque, scarcely liquefiable mass. With more soda it first swells up, but can afterwards, in a strong heat, be fused to a bead.

With the solution of cobalt it becomes more infusible, but gives on the fused edges a fine dark blue glass.

9. *Black primitive hornblende*, from Slättmyra.

Alone it swells up very little, and fuses to a black, brilliant bead.

It dissolves with borax into a glass tinged with iron.

It is not decomposed by the salt of phosphorus. The fragment remains unchanged, and retains its color, becomes afterwards rounded on the edges, and acquires a tinge of iron. In this respect it resembles the non-aluminiferous amphibole.

With soda it fuses to a black, brilliant glass, which is rendered more fusible by a farther addition of the flux, but it then acquires a dull, crystalline surface, and a dark brown color.

10. *Black hornblende*, in broad laminæ, from Taberg, in the district of Norberg, behaves like the preceding variety.

11. *Dark green, foliated hornblende*, from Annaberg, in Saxony.

Alone it fuses with intumescence into a black, lustrous glass.

It is readily dissolved by borax to a slightly colored glass.

It is decomposed by salt of phosphorus, after being heated for some time, and gives a siliceous skeleton. The bead is colorless, and becomes opalescent on cooling.

With soda it behaves like  $\gamma$ .

$\lambda$ . *Black, crystallized hornblende*, from Pargas, fuses with strong intumescence and readily into a greyish-brown, opaque glass.

Borax dissolves it readily to a transparent, greenish glass.

With the salt of phosphorus it is decomposed into a glass which resembles ice in appearance, and is colored by iron as long as it remains hot, but it becomes opalescent on cooling.

It fuses with difficulty with soda into a greyish-brown glass, which is not easily fused to a bead.

$\mu$ . *Pargasite*, or transparent, light green, crystallized hornblende, from Pargas.

It behaves exactly like the preceding, except that the glass is less strongly colored with iron. It differs from the last variety only in containing a less amount of iron.

*Two-thirds silicate of lime, with two-thirds silicate of magnesia.*  $\text{Pyroxene, Ca}^3\text{Si}^2 + \text{Mg}^3\text{Si}^2, (\text{C S}^2 + \text{M S}^2).$

a. *White or colorless, translucent pyroxene.*

*Diopside or Alalite*, from Piedmont.

*White malacolite*, from the Tammare lime quarry in Finland.

*White malacolite*, from Tjötten, in Norway.

*Salite*, light green variety from Sala; all these have the composition represented by the above formula.

Alone, they fuse with slight effervescence, to a colorless, semi-transparent glass.

They readily dissolve with borax to a transparent glass.

They are slowly decomposed by salt of phosphorus, and leave a siliceous skeleton. The transparent glass becomes opalescent on cooling. Diopside remains for a long time transparent and unchanged, but finally swells up, and is converted into a siliceous skeleton.

With a small proportion of soda they swell up and dissolve into a liquid, transparent glass, which becomes opaque and less fusible on the addition of more soda. As each new portion of soda is added, they swell up anew before fusing.

The malacolite from Finland becomes red on the fused edges when heated with the solution of cobalt; diopside also acquires a red color on its thin fused edges, or, if fused to a bead, it

becomes violet; malacolite from Tjötten becomes blue,\* bordering on red.

*Remark.* Among the specimens of the so-called Salite from Sala, there occurs a malacolite, which cannot be distinguished from common Salite except by a lower degree of lustre and hardness, as it exactly resembles it in form and color. This variety contains 5 per cent. of lime, and is, according to Rose's analysis, principally a silicate of magnesia; its behavior is as follows:

Alone in the matrass it gives off water; on charcoal it burns greyish-white, but does not fuse, either in fragments or when pulverized, but only sinters and becomes dark and glassy on the edges.

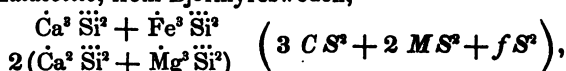
With borax and soda it behaves like the preceding.

It is dissolved by salt of phosphorus, with about the same degree of difficulty as the preceding varieties, but the fragment does not retain its translucency and color, as the others do, but becomes enamel-white, and then begins to swell up slowly, and is converted into a siliceous skeleton.

With the solution of cobalt it gives a dirty red color, both on the fused edges, as well as through the whole mass, and the oxide of cobalt renders it more fusible. The contrary is the case with the malacolites containing lime.

b. *Pyroxene, which contains a larger number of atoms of lime than of magnesia.*

*Malacolite*, from Björmyresweden,



fuses readily to a dark glass.

With borax, salt of phosphorus and soda, it behaves like the preceding, except that it gives a glass colored with iron.

c. *Pyroxene, containing silicate of the protoxide of iron as a constant ingredient.*

a. *Hedenbergite*, from Mormorsgrufva, near Tunaberg,  
 $\text{Ca}^3 \ddot{\text{Si}}^2 + \text{Fe}^3 \ddot{\text{Si}}^2, (\text{CS}^2 + f\text{S}^2).$

Alone it gives off no water, or only hygroscopic moisture, which when the assay is heated to the melting-point of glass has a slightly acid reaction. In the forceps it fuses, after boiling a very little, into a black, brilliant glass.

Borax dissolves it into a glass tinged with iron.

Salt of phosphorus decomposes it slowly to a siliceous skele-

\* This is perhaps owing to one half per cent. of alumina which is contained in the mineral.

ton, in which the undecomposed substance appears with a brilliant, black lustre. The color of iron disappears as the bead cools.

Soda dissolves it with difficulty to a black glass, which becomes dull upon the surface with the addition of more soda, and it requires a far larger quantity of that flux than either of the preceding varieties, before it becomes slaggy.

$\beta$ . *Greenish-black pyroxene*, from Taberg near Philipstad, and from Arendal, and *Dark red malacolite* from Dagerö in Finland, behave like the preceding.

d. *Pyroxene, containing alumina and generally black.*

a. *Pyroxene*, from Pargas, and

$\beta$ . *Pyroxene* from Auvergne,  $\text{Ca}^3 \ddot{\text{Si}}^2 + \left\{ \begin{array}{c} \dot{\text{Mg}}^3 \\ \dot{\text{Fe}}^3 \end{array} \right\} \left\{ \begin{array}{c} \ddot{\text{Si}}^2 \\ \ddot{\text{Al}}^3 \end{array} \right\}$

$\left( \text{CS}^2 + \frac{\text{M}}{f} \right) \left\{ \frac{\text{S}^2}{\text{A}^3} \right\}$ , in lava, behave like pyroxene in general, but are far more difficultly, or not at all, dissolved by salt of phosphorus; the fragment becomes translucent and less deeply colored; with soda they give a less fusible glass, so that they become infusible with a quantity of soda, with which the dark-green varieties, containing iron as a constant ingredient, would form a glass.

*Two-thirds silicate of alumina and the protoxide of iron.*

a. *Diallage*,\*  $\dot{\text{Fe}}^3 \ddot{\text{Si}}^2 + 3 \dot{\text{Mg}}^3 \ddot{\text{Si}}^2, (f\text{S}^2 + 3\text{MS}^2)$ .

Alone in the matrass it gives off water, which is not acid, cracks, and acquires a lighter color. On charcoal it fuses with difficulty on the edges to a greyish slag.

It dissolves with difficulty with borax to a transparent glass, colored by iron.

It is decomposed by the salt of phosphorus, and leaves a siliceous skeleton.

With a certain portion of soda, it fuses to an opaque, greyish-green bead; with a larger quantity, it swells up and becomes infusible. On platina foil it gives traces of manganese.

b. *Hypersthene*,  $\dot{\text{Fe}}^3 \ddot{\text{Si}}^2 + \dot{\text{Mg}}^3 \ddot{\text{Si}}^2 (f\text{S}^2 + \text{MS}^2)$ .

Alone in the matrass it cracks a little and gives off water, which is not acid, but it does not change its appearance particularly. On charcoal, it fuses with difficulty to a greyish-green glass.

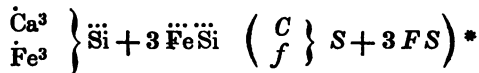
\* I do not know the locality of the hypersthene and diallage used in these examinations, but as both specimens were presented me by M. Haüy, I can have no doubt that they are rightly named.

With borax, it fuses readily to a greenish glass.

Salt of phosphorus does not appear to attack it, but it becomes rounded on the edges, and is dissolved with the greatest difficulty.

It behaves with soda like the preceding.

*One-third silicate of lime and the protoxide of iron, with one-third silicate of the peroxide of iron,*



*Jenite, Lievrite, from Elba.*

Alone in the matrass, it gives off water, which has not an acid reaction, and which seems to be only mechanically enclosed in the mineral, since its appearance undergoes no change. On charcoal it fuses readily to a black bead, which becomes vitreous in the exterior flame; in the interior flame it acquires a dull surface, and becomes attractable by the magnet, which is not the case with the mineral when it is simply ignited.

It dissolves readily with borax to a dark, almost opaque glass, which is colored with iron.

Salt of phosphorus decomposes it, leaving a siliceous skeleton; the glass is strongly colored by iron.

With soda it fuses to a black glass. On platina it exhibits traces of manganese.

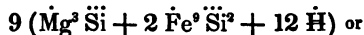
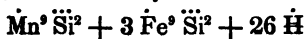
*Addition. Cronstedtite, from Przibram in Bohemia.†*

Alone in the matrass it gives off water, which, when driven off by ignition in the open tube, exhibits traces of fluoric acid.

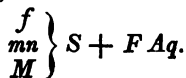
Alone on charcoal or in the forceps it fuses slowly on the edges into a black glass, which is dull on the surface.

\* The formula does not agree exactly with the results of the analysis, but is the most probable which can be given.

† If Steinmann's analysis of this mineral be calculated, (Neues Journal für Chemie u. Physik, von Schweigger und Meineke III. p. 269,) it would appear to consist of one-third silicates of magnesia, combined with silicates of the protoxides of iron and manganese, in which the bases contain 1.2 times as much oxygen as the silica, and water of crystallization. The resulting formula is:



$(mn^3 S^3 + 9 MS + 21 f^3 S^2 + 45 Aq)$ ; however, this formula ought not to be adopted without renewed investigation. According to Von Kobell its composition is,





It is readily dissolved by borax and salt of phosphorus, giving the reaction of the protoxides of iron and manganese.

With soda on charcoal it gives readily a black glass, which becomes infusible with the addition of more soda, and with a still larger quantity it is absorbed by the charcoal. On platina foil it gives distinct traces of manganese.

F. *Silicates of lime and magnesia, with alumina, in which the alkaline earths are often replaced by the protoxides of iron and manganese, and the alumina by the peroxide of iron.*

*One-third silicate of lime and alumina.*

a. *Epidote*,  $\text{Ca}^3 \ddot{\text{Si}} + 2 \ddot{\text{Al}} \ddot{\text{Si}}$ , (*C S + A S*).

a. *Zoisite*, from Baireuth and Carinthia.

Alone it swells up and thickens at right angles to the laminae; when first heated, it emits a number of small bubbles, which disappear at a higher temperature. On the extreme edges it fuses to a transparent, yellowish glass, but the swollen mass is afterwards very difficultly fusible, and forms a vitreous slag.

With borax it swells up and dissolves to a transparent glass.

With salt of phosphorus, it intumesces and dissolves readily with effervescence, leaving a siliceous skeleton.

A very small quantity of soda dissolves it to a slightly greenish glass, but with the usual quantity it swells up into a white infusible slag. On platina it exhibits traces of manganese.

With the solution of cobalt it gives a blue glass.

TURNER obtained in many varieties of Zoisite the reaction of boracic acid, by the aid of bisulphate of potash and fluor spar.

b. *Pistacite*, from Bourg d'Oisan, Hellestad, Arendal, Ta-  
berg and Orrjårfwi,  $\begin{matrix} \text{Ca}^3 \ddot{\text{Si}} + 2 \ddot{\text{Al}} \ddot{\text{Si}} \\ \text{Fe}^3 \ddot{\text{Si}} + 2 \ddot{\text{Al}} \ddot{\text{Si}} \end{matrix}$  (*C S + f S + 4 A S*).\*

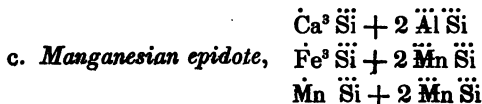
Alone, it fuses first on the extreme edges, swells up into a dark brown, cauliflower-like mass, which, at a higher temperature, becomes black and rounded, but does not really liquefy. The variety from Arendal, which, according to analysis, contains the largest amount of iron, is considerably more fusible than the others.

With borax it first swells up, and then dissolves to a glass, colored by iron.

Salt of phosphorus decomposes it, with intumescence, and leaves a siliceous skeleton.

\* This formula is, perhaps, only applicable to the variety which is found at Bourg d'Oisan, in France.

With a certain proportion of soda, it fuses difficultly to a dark glass, which, with more soda, is converted into a slag.



$\left( \begin{smallmatrix} c \\ f \\ mn \end{smallmatrix} \right) S + 2 \begin{smallmatrix} A \\ Mn \end{smallmatrix} \left. \right\} S$  from St. Marcet, in Piedmont.

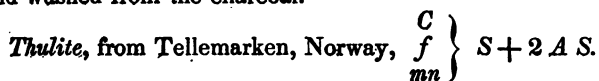
Alone it fuses readily, with intumescence, into a black glass.

With borax it dissolves, with effervescence, into a transparent glass, which acquires an amethystine tinge in the exterior flame, but in the interior flame it exhibits the color of iron while hot, and becomes colorless on cooling.

In the salt of phosphorus, it swells up and dissolves, leaving a siliceous skeleton; the glass exhibits the color of iron, and not of manganese, as long as it remains hot.

With soda, it behaves like the preceding varieties, but with a large amount of soda on platina foil a dark green mass is obtained, which flows away from the assay.

All varieties of epidote give globules of tin, when reduced and washed from the charcoal.



Behaves like the preceding.

g. *Idocrase*. Its formula is not known with certainty, but it is, in all probability, the same as that of garnet, with the same substitutions of its elements.

a. *Common idocrase* or *Vesuvian*, from Vesuvius, Eger and Fassa, fuses very readily, with intumescence, to a dark glass, which, when treated in the external flame, can be rendered yellow and translucent.

It is readily dissolved by borax to a transparent glass, colored by iron.

With soda it gives a glass, but less readily than garnet; with a larger portion of the flux, it is converted into a slag.

*Remark.* Idocrase dissolves more readily in borax and salt of phosphorus, because it has the property of intumescing at a certain temperature. Since this intumescence takes place within the flux, it gives it an opportunity of penetrating into the assay and acting in many points at once. It fuses, on the other hand, less readily with soda, because it contains less iron. TURNER states that he obtained traces of boracic acid in several

varieties of idocrase, by means of bisulphate of potash and fluor spar.

b. *Magnesian idocrase* or *Loboite*, from the lime quarries of Gökum and Frugård.

Heated alone, it becomes opaque, splits, and then fuses readily, with intumescence, to a green or yellowish bead, which seems to contain heterogeneous particles.

It dissolves instantly, with intumescence, with borax.

With salt of phosphorus and soda it behaves like the preceding.

c. *Cyprine*, idocrase containing copper, from Tellemarken, in Norway.

Gently heated its fine blue color remains unchanged. It appears black as long as it remains hot, but the blue color returns as soon as it becomes cold. It fuses readily, with strong intumescence, to a blebby bead, which is black in the oxidating flame, but red from the protoxide of copper in the reducing flame.

It is readily dissolved by borax; the glass is transparent and becomes green in the oxidating flame. In the reducing flame it is colorless, and, unless the glass is fully saturated, the reaction of copper cannot be obtained without the aid of tin.

It is quickly decomposed by salt of phosphorus; it swells up into a mass resembling ice, which is green on cooling, and when treated in the interior flame it becomes red on the surface. If too much of the salt of phosphorus be employed, the green color can be obtained, but not the red, without the aid of tin.

With soda it gives a black glass, and bears more of this flux than the preceding. A large quantity of copper is obtained by reduction.

γ. *Essonite*; the formula is not known with certainty, but is probably the same as that of garnet.

a. *Essonite*, from Ceylon, *Cinnamon stone*.

Alone it does not become darker when heated; it fuses readily; at first the glass has the same color as the mineral, but it afterwards becomes green; in both cases it remains transparent.

With borax it dissolves readily to a transparent glass, which is colored with iron.

With the salt of phosphorus it behaves like common idocrase.

With soda it fuses to a green glass, which becomes a grey, difficultly fusible slag, on the addition of more soda.

b. *Essonite*, from Brazil.

Its dark red color does not become more intense when heat-

ed ; it fuses readily to a black bead, which appears metallic on the surface, but does not act strongly on the magnet.

With borax it is dissolved with great facility to a glass colored with iron.

Salt of phosphorus dissolves it, as it does the preceding.

It is decomposed by soda ; with a small quantity it gives a black glass, with more, an infusible slag.

#### δ. Garnet.

Although the composition of the two preceding varieties agrees so nearly with that of the garnet that they may be considered identical, there is a marked difference between them both in their crystalline form and in their behavior before the blowpipe, as well as in slight peculiarities of composition, so that we may conclude that some important ingredient is contained in the latter mineral, which has thus far escaped notice.

The formula of the garnet is  $\ddot{R}^3\ddot{Si} + \ddot{R}\ddot{Si}$ .  $\ddot{R}$  in the first member of the formula denotes often a mixture of  $\ddot{Ca}$ ,  $\ddot{Mg}$ ,  $\ddot{Fe}$ ,  $\ddot{Mn}$ , and  $\ddot{R}$  in the last term generally a mixture of  $\ddot{Al}$  and  $\ddot{Fe}$ . The varieties of garnet can therefore be divided into, 1st, those which contain  $\ddot{Ca}$  in the first term of the formula, 2d, those which contain chiefly  $\ddot{Fe}$  or  $\ddot{Mn}$  in the first term, and 3d, those which contain chrome, which according to TROLLE-WACHTMEISTER's researches exists in the state of brown oxide, and not as an acid, in this mineral.\*

##### 1. Lime garnet, *Aplome*.

##### a. Black garnet, from Frascati, *Melanite*.

Alone it fuses to a black brilliant globule, without effervescence.

It is slowly and difficultly dissolved by borax, and gives a glass colored by iron.

Salt of phosphorus dissolves it slowly, leaving a siliceous skeleton. The color of iron disappears on cooling.

Soda forms with it a black bead, which becomes less fusible on the addition of more soda, but which can, however, be fused after the excess of the flux is absorbed by the charcoal. On platina foil it gives traces of manganese.

β. Green garnet, from Sala, fuses with strong intumescence to a black, brilliant glass.

\* A. MAUS endeavored to show (in Poggendorff's Annals, vol. IX. p. 127,) that this oxide is not an exact atomic combination ; his researches only prove that it contains chromic acid as it is generally obtained, and that it can be so decomposed by reagents that chromic acid and protoxide of chrome are formed. Can it be supposed that there is not such a combination as  $Cr + 2 O$  ?

With borax and salt of phosphorus it behaves like the preceding.

It is decomposed by soda and swells up, but afterwards fuses to a black, brilliant bead. On platina foil it exhibits a trace of manganese.

*r. Light brown garnet*, from Danemora, fuses, without intumescence, to a black, brilliant bead.

It is dissolved by borax to a transparent glass, which acquires a dirty amethystine color in the oxidating flame, but in the reducing flame it is tinged with the characteristic color of iron.

With salt of phosphorus it behaves like the preceding.

With soda it becomes green at first, then intumescs and fuses to a black bead with a metallic lustre.

*s. Dark brown or black garnet*, from Långbanshyttan, *Rothsiffite*.

Alone it fuses with difficulty to a black, dull or semi-vitreous globule.

It is slowly dissolved by borax to a dark green glass.

With the salt of phosphorus it behaves like the preceding.

With soda it swells up into a black glass; on platina foil it gives traces of manganese.

*t. Red garnet*, from the lime quarry at Kulla in Finland, *Romanzovite*.

Heated alone it becomes darker, but not opaque. It fuses with considerable intumescence to a blebby bead.

It is dissolved by borax with the greatest difficulty. By long-continued heating it becomes green, first on the edges and then in the centre, and gives out a greener light than the glass which surrounds it. At length it is entirely dissolved.

It behaves like the preceding variety with the salt of phosphorus.

With soda it intumescs, and then fuses to a green glass, which liquefies less readily on the addition of more soda. On platina foil it exhibits traces of manganese.

*Remark.* It resembles the cinnamon-stone of Ceylon both in composition and in its external characters. NORDENSKJÖLD'S formula is  $FS + 3 CS + 5 AS$ , while KLAPROTH'S analysis of cinnamon-stone gives  $FS + 4 CS + 5 AS$ . Both occur in lime.

*u. Allochroite*, from Berggieshübel, in Saxony.

Alone it fuses readily without intumescence to a black, brilliant glass.

With borax it dissolves readily into a glass colored by iron.

With the salt of phosphorus and soda it behaves like the preceding. On platina foil it exhibits faint traces of manganese.

2. Garnet containing the protoxides of iron and manganese, *Almandine*.

a. *Fahlun garnet*,  $\text{Fe}^{\text{a}} \ddot{\text{Si}} + \ddot{\text{Al}} \ddot{\text{Si}}$ .

Alone it grows darker when heated, but acquires its original color on cooling. It fuses, without the least intumescence, to a black bead, which is dull and metallic on the surface as if covered with a crust of reduced iron. The bead shrinks together on cooling so as to form a cavity on one side of the mass. It has a vitreous fracture.

It is dissolved with great difficulty by borax into a dark glass colored by iron. The undissolved portion looks quite dark in the glass.

It is decomposed by salt of phosphorus and intumescs. The skeleton is white, spotted with black, but becomes colorless if the heat is continued. As long as the bead holds together the glass is transparent on cooling, but if the blast be continued so long that it crumbles in pieces, the bead becomes opalescent on cooling.

It is dissolved by soda, first intumescing, and then dissolving to a black bead having a metallic lustre; a larger quantity of soda does not affect its fusibility. On platina foil it exhibits traces of manganese.

β. *Finbo garnet*,  $\text{Fe}^{\text{a}} \ddot{\text{Si}} + \ddot{\text{Fe}} \ddot{\text{Si}}$   
 $4 (\text{Mn}^{\text{a}} \ddot{\text{Si}} + \ddot{\text{Al}} \ddot{\text{Si}}) (f S + F S + 4 mn S + 4 A S).$

Alone on charcoal it behaves like the preceding, with this difference, that the fused bead has a metallic lustre only on portions of its surface.

It is dissolved by borax like almandine, but the saturated glass acquires an amethystine tinge in the oxidating flame.

With salt of phosphorus, it behaves like the preceding.

It is decomposed by soda, and with a small proportion of the flux it fuses readily to a black bead. More soda lessens its fusibility, till it no longer liquefies. On platina foil it gives decided evidence of the presence of manganese.

γ. *Broddbo garnet*,  $\text{Fe}^{\text{a}} \ddot{\text{Si}}^2 + \ddot{\text{Al}} \ddot{\text{Si}}$   
 $\text{Mn}^{\text{a}} \ddot{\text{Si}} + \ddot{\text{Al}} \ddot{\text{Si}} (f S^2 + mn S + 2 A S).$

Alone it fuses and boils, giving a black bead with a highly vitreous surface.

With borax and soda it behaves like the preceding.

With salt of phosphorus the same is true, except that the bead is less opalescent on cooling.

3. *Chrome garnet, Pyrope.* According to VON KOBELL, the formula of the pyrope is,  $\left. \begin{smallmatrix} M \\ f \\ C \end{smallmatrix} \right\} S + \frac{A}{Cr} \left. \right\} S.$

a. *Pyrope*, from Ceylon, becomes, when heated, darker colored, and finally, black and opaque; seen by transmitted light when cooling, it becomes dark green, then chrome-green, then colorless, and finally returns again to its original fiery red. It fuses with difficulty, without intumescence, to a black, brilliant glass.

With borax it dissolves, and gives a glass which has a more or less beautiful chrome-green color, in proportion to the quantity of the flux.

It is very slowly dissolved by the salt of phosphorus, leaving a siliceous skeleton. The glass acquires a green color before the assay is decomposed. The fragment remains for a long time undissolved, retaining its red color, but at length gradually becomes converted into a siliceous skeleton. The bead is opalescent on cooling, and becomes chrome-green.

It is decomposed by soda, but hardly dissolved; it forms a reddish-brown, slaggy bead.

β. *Pyrope*, from Bohemia, becomes black and opaque when heated; seen by transmitted light as it cools, it changes from a dirty yellow to red, and when entirely cold, it recovers its original color.

With borax it dissolves to a glass strongly colored by iron, without a distinct tinge of chrome-green.

With salt of phosphorus it behaves like the preceding, except that the glass is not so strongly tinged with green.

With soda it behaves like the preceding.

*Uwarowite*,  $\left. \begin{smallmatrix} \text{Ca}^3 \\ \text{Fe}^3 \end{smallmatrix} \right\} \ddot{\text{Si}} + \frac{\ddot{\text{Al}}}{\ddot{\text{Cr}}} \left. \right\} \ddot{\text{Si}}$ , from Biserak, Siberia.

Alone in the matrass, it gives off water, and acquires a dingy, opaque, yellowish color as long as it remains hot, but on cooling it becomes green again.

In the forceps it is infusible; on the edge, where the heat was greatest, it becomes darker colored and brownish.

It is taken up by borax with exceeding slowness. The glass is chrome-green.

It is also very slowly dissolved by salt of phosphorus. The glass exhibits the usual play of colors of the oxide of chrome; while hot it is transparent, and has a purple tinge; afterwards

it becomes opaque, but when entirely cold, it has a fine, clear, emerald-green color.

With soda on charcoal it forms a greenish-yellow slag. On platina the melted soda around the assay is tinged with the characteristic yellow of chromic acid.

*One-third silicate of lime, with one-sixth silicate of alumina.*

$$2 \text{Ca}^{\circ} \ddot{\text{Si}} + \left. \begin{array}{c} \ddot{\text{Al}}^3 \\ \ddot{\text{Fe}}^3 \end{array} \right\} \ddot{\text{Si}}, \text{ Gehlenite, from Monzoni, in the Fassa valley.}$$

Alone it does not fuse or undergo any change.

With borax it dissolves with great difficulty to a glass which is faintly colored by iron.

With the salt of phosphorus it gradually becomes translucent on the edges, without intumescing, and afterwards dissolves entirely.

With soda it intumescs, but does not fuse.

With the solution of cobalt it gives a dark dingy blue.

*Addition. Anthophyllite, from Greenland.*

Alone, either in fragments or pulverized, it remains unaltered and infusible.

With borax it dissolves with difficulty; the glass is colored by iron.

With salt of phosphorus it dissolves slowly, leaving a siliceous skeleton.

With soda it fuses slowly to a slaggy mass. It does not exhibit traces of manganese.

*Two-thirds silicate of alumina and magnesia, (3 Mg<sup>3</sup>  $\ddot{\text{Si}}$  + 2  $\ddot{\text{Al}}$   $\ddot{\text{Si}}$  + 3  $\ddot{\text{H}}$ ) + 4 (Mg<sup>3</sup>  $\ddot{\text{Si}}$  + 3  $\ddot{\text{H}}$ ), (3 MS + 2 AS + Aq) + 4 (MS<sup>2</sup> + Aq), Soapstone, from Cornwall.*

Alone in the matrass it gives off water and blackens. On charcoal it burns white again, and then fuses to a colorless, blebby glass.

It is slowly but perfectly dissolved by borax to a transparent glass.

With salt of phosphorus it behaves like the preceding.

With soda an imperfectly fused, semi-transparent glass can be obtained at a high temperature; it does not become more fusible on the addition of more soda.

With the solution of cobalt it acquires a dirty dark violet color, but is blue on the fused edges.

*Saponite, 2 Mg<sup>3</sup>  $\ddot{\text{Si}}$  +  $\ddot{\text{Al}}$   $\ddot{\text{Si}}$  + 6  $\ddot{\text{H}}$  (2 MS<sup>2</sup> + AS + 2 Aq), from the mine of Bruksved-Swartwick, Dalecarlia.*



Alone in the matrass it gives off water, which smells burnt, and blackens.

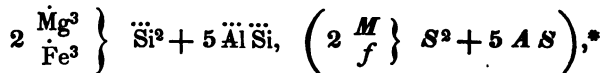
In thin splinters it fuses to a blebby enamel, which cannot be melted to a bead.

With borax and salt of phosphorus it behaves like the preceding.

It fuses with soda to a clouded glass.

*Two-thirds silicate of magnesia, with one-third silicate of alumina, Dichroite.*

a. *Blue dichroite,*



*Iolite, Steinheilite, Cordierite, Saphir d'eau,* from Orrjerfvi and from Sala.

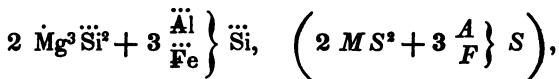
Alone it remains unchanged at a moderate heat; at a higher temperature it fuses with difficulty on the edges to a glass, which has the same color and degree of transparency as the mineral itself.

With borax and salt of phosphorus it behaves like the preceding.

Soda does not dissolve it; with a small proportion of the flux it gives a dark-grey, vitreous slag; with more it swells up and becomes infusible.

With the solution of cobalt it becomes black, but on the fused edges, greyish-blue.

b. *Red dichroite,*



*Hard Fahlunite,* from Fahlun.

Alone in the matrass it gives off water, loses its color, becomes white and semi-transparent. On charcoal it fuses to a colorless, semi-transparent glass.

Borax dissolves it slowly, but in large quantity, to a transparent glass, which cannot be rendered opaque by flaming.

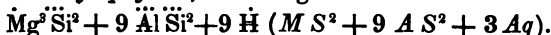
It is dissolved by the salt of phosphorus like the preceding.

With a certain proportion of soda it dissolves to a very difficultly fusible, colorless, semi-transparent glass. With more soda it swells up and becomes infusible.

\* This formula is calculated from an analysis of the dichroite, from Orrjerfvi, furnished to me privately by Bonsdorff.

With the solution of cobalt it does not give a decided color till after it is fused, when it forms a blue glass.

*Two-thirds silicate of magnesia, with two-thirds silicate of alumina. Pyrophyllite, from Blagodadskoi.*



In the matrass it gives off a very little water, and acquires the same silvery lustre which some kinds of mica do. Thick fragments sometimes split and decrepitate.

In the forceps it splits longitudinally and exfoliates, afterwards at a higher temperature it swells up in all directions, with a vermicular movement, into various distorted, snow-white forms, which are infusible, and seem to consist of small scales. It has a greasy feel, with hard points interspersed in the mass.

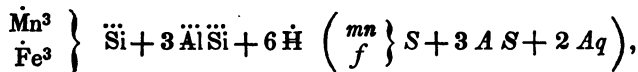
It is readily dissolved by borax and in large quantity to a transparent, colorless glass.

With the salt of phosphorus it gives a very much swollen siliceous skeleton, which gradually dissolves, and the glass becomes opalescent.

With soda it gives a transparent, colorless glass.

With the solution of cobalt a fine blue color is obtained.

*One-third silicate of the protoxides of iron and manganese, with one-third silicate of alumina.*



*Carpholite, from Schlackenwald, in Bohemia.* It also contains 0.0147 per cent. of fluoric acid, which is not included in the formula.

Alone in the matrass it gives off water, which, after the assay has been ignited, is acid, attacks the glass and colors Brazil-wood paper yellow. The glass is spotted with silica deposited by the fluoric acid. On charcoal it first swells up and becomes whiter, and then fuses to an opaque, brownish glass, which acquires a considerably darker shade of color in the exterior, than in the interior flame.

It is readily dissolved by borax to a transparent glass, which is colored with manganese in the exterior flame, but acquires a faint greenish tinge in the interior flame.

With salt of phosphorus it swells up and gives a siliceous skeleton resembling ice, but this skeleton fuses very readily and gives a transparent glass, which becomes strongly opalescent on cooling. In the oxidating flame it acquires a distinct amethystine color.

Treated with soda on charcoal it does not dissolve; the fragment swells up and acquires a fine green color. On platina foil, on the contrary, if a sufficient quantity of soda is added, it dissolves and forms a fusible, dark green mass.

With the solution of cobalt it acquires a dark, and somewhat dirty, blue color.

G. *Silicates of alumina and metallic oxides.*

*Basic silicate of alumina and peroxide of iron. Staurotide, from St. Gothard.*

Alone in fragments it undergoes no change, and does not fuse, but acquires a darker color, inclining to black. If finely pulverized, it can be fused on the edges to a black slag.

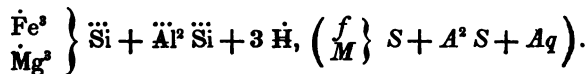
It is slowly dissolved by borax into a clear, dark green glass, which is colored by the protoxide of iron.

It is very slowly dissolved by the salt of phosphorus, unless pulverized. In that case it leaves very little or no silica undissolved; the bead, while hot, is greenish-yellow and transparent, but loses its color and becomes opalescent on cooling.

It is not dissolved by soda, but combines with it with effervescence, and gives a yellowish slag.

With the solution of cobalt it does not become blue, but acquires in the fused portion a dark color, which inclines to a dirty blue.

*Basic silicate of alumina and protoxide of iron. Chlorite spar or Chloritoid, from Kassoibrod, near Catherinenburg.*



Alone in the matrass it gives off a small quantity of water, and becomes brown.

In the forceps it exfoliates, and acquires a slaggy appearance on its extreme edges, but even if pulverized it does not show the least signs of fusion.

In the reducing flame it becomes blackish-brown, and splits.

It is very slowly taken up by borax, and the glass is colored green by iron. The undissolved portion, as long as any remains, is black.

Its behavior with salt of phosphorus is the same, except that the color of the glass is far paler. When pulverized it dissolves, leaving a siliceous skeleton, which remains partially undissolved, and gives the bead an opalescent appearance.

Soda does not attack it at all, either on charcoal or platina ; it does not exhibit traces of manganese.

*Basic silicate of alumina and oxide of copper.* *Allophane*, from Saxony.

Alone in the matrass it gives off water, and becomes black in spots. It becomes evident that the mass is a heterogeneous mixture, and that it is traversed by white layers which do not become colored. The water has a slightly acid reaction on litmus-paper.

On charcoal or in the forceps it does not fuse, but swells up, crumbles, and tinges the flame with the characteristic green color of copper.

It is dissolved by borax with the greatest difficulty to a colorless glass, which is slightly reddish in the interior flame, and, with the addition of tin, opaque and colored red by the protoxide of copper.

It is readily decomposed by the salt of phosphorus, and leaves a siliceous skeleton, showing indistinctly the characteristic color of copper. With the addition of tin, the glass is red.

It is not dissolved by soda ; the mass is green in the oxidating flame, and red in the reducing flame ; with the addition of borax, a button of metallic copper can be obtained.

#### H. *Silicates containing glucina and alumina.*

##### *Silicate of alumina and glucina.*

a. *Emerald, Beryl*,  $\ddot{G}\ddot{Si}^2 + 2\ddot{Al}\ddot{Si}^2$ , ( $G S^2 + 2 A S^2$ ).

Alone at a moderate temperature it remains unchanged. In thin splinters, if strongly heated for a long time, it becomes rounded on the edges, and forms a colorless, blebby slag. The transparent portion becomes milk-white when exposed to the action of the strongest possible flame.

With borax it dissolves to a transparent, colorless glass. The variety colored by chrome gives a glass, which acquires on cooling a faint, but beautiful tint of green.

It is slowly dissolved by salt of phosphorus, without leaving a siliceous skeleton ; the fragment remains unchanged in appearance, but gradually diminishes in size, and gives a bead, which becomes opalescent on cooling. The glass is colored green by the variety which contains chrome.

Soda dissolves it to a transparent, colorless glass. The yellowish variety with a granular fracture, from Broddbo and Finbo, gives, by the process of reduction, distinct traces of tin.

With the solution of cobalt it gives a dingy color, which can hardly be called blue.

b. *Eucrase*,  $\ddot{\text{G}} \ddot{\text{Al}} + 3 (\ddot{\text{G}} \ddot{\text{Si}} + \ddot{\text{Al}} \ddot{\text{Si}})$ , ( $G A + 3 G S + 3 A S$ ).

Moderately heated alone it remains unaltered. At a higher temperature it swells up, becomes white, throws out cauliflower-like ramifications, and fuses in a strong heat on its thin edges to a white enamel.

In borax it swells up with effervescence, and becomes white. Afterwards it gradually dissolves to a transparent, colorless glass. It is very difficult to dissolve perfectly the last portions. The glass cannot be rendered opaque by flaming.

It is dissolved by salt of phosphorus with slight effervescence, which very soon ceases. It gives a siliceous skeleton, whiter than usual, which does not become more minutely divided. The glass is, otherwise, transparent and colorless, but becomes opalescent on cooling.

With a certain proportion of soda it fuses to an opaque bead; with more soda it gives a transparent glass, which becomes cloudy on cooling; a still larger portion of soda sinks into the charcoal, and the residuum fuses as before. By reduction a trace of tin is obtained.

*Basic silicate of alumina with aluminate of glucina*,  $\ddot{\text{G}} \ddot{\text{Al}}^3$ , ( $G A^3$ ), *Cymophane*, *Chrysoberyl*, from Ceylon and Connecticut.

Alone it undergoes no change. Pulverized, the edge of the mass acquires a vitreous appearance in an intense heat, but does not fuse.

It is slowly dissolved by borax to a transparent glass, which does not become opaque at any degree of saturation.

Salt of phosphorus dissolves it slowly and completely to a transparent glass, which does not become opalescent on cooling.

It is not attacked by soda, and does not swell up; the fragment becomes dull upon the surface. Soda does not decompose even the pulverized mineral.

With the solution of cobalt it acquires a fine blue color, but does not fuse.

*One-third silicate of glucina and peroxide of iron, with two-thirds silicate of the protoxide of manganese and oxysulphuret of manganese*. *Helvine*, from Schwarzenberg in the Saxon Erzgebirge. The analysis of this singularly constituted mineral, by CHR. GMELIN, gives the following formula:  $3 (\text{Mn Mn} + 3 \text{Mn Si}^2) + (\text{G}^2 \text{Si}^3 + \text{Fe Si})$ , in which it is taken

for granted that the iron exists in the mineral in the state of peroxide and not of protoxide, with which supposition the color of the mineral, as well as the loss in the analysis, agrees very well.

Alone in the matrass it gives off water, without losing its sulphur-yellow color, or its transparency. On charcoal it fuses in the interior flame, with effervescence, to an opaque bead of nearly the same color as the mineral. In the exterior flame it is far less fusible, and acquires a dark color.

It is slowly dissolved by borax to a transparent glass, which, so long as any portion of the assay remains undissolved, is yellow, which color it retains partially on cooling. This color is caused by the formation of sulphuret of sodium. After all is dissolved, it becomes colorless in the interior flame, and strongly amethystine in the exterior flame; but the shade of color in the latter case is less clear.

It is tolerably easily dissolved by salt of phosphorus, leaving a siliceous skeleton. The glass is colorless, cold or hot, but it becomes opalescent on cooling.

With soda it swells up at first, and then fuses to a black bead, which becomes chestnut-brown in the reducing flame. On platina foil it swells up at first, divides and becomes chestnut-brown without coloring the soda; but if the heat be continued it acquires the color of manganese, and is converted into chameleon mineral.

If a large quantity of soda is added, so that the mass liquefies on the charcoal, and the whole be then laid on silver foil and moistened with water, the silver is blackened. With a solution of helvine in soda glass it is not possible to obtain distinct traces of sulphur.

#### I. *Silicates containing yttria and protoxide of cerium.*

*One-third silicate of yttria, with one-sixth silicate of the protoxide of cerium and iron. Gadolinite*, from Ytterby, Finbo, and Broddbo. The Gadolinite is a mixture of basic silicates. The bases are: yttria, terbina, proto-peroxide of erbium, glucina, protoxide of cerium, oxide of lanthanum, proto-peroxide of iron, and protoxide of manganese.

The Gadolinite is of two kinds, of which the first, ( $\alpha$ ) is vitreous, and resembles black glass; the other, ( $\beta$ ) has a splintery and less conchoidal fracture than the other. It seems to be an intimate mixture of Gadolinite and orthite.

Var.  $\alpha$ . Alone in the matrass it undergoes no change, and

does not give off water; if the matraass is heated almost to the melting point, the assay gives out a momentary light as if it had taken fire; it swells up a little, and, if the fragment is large, it cracks and acquires a light, greyish-green color. Nothing volatile escapes from it. On charcoal the same appearance is noticed; it does not fuse, but in a strong heat it blackens on its thin edges.

Var.  $\beta$ . Alone it swells up into cauliflower-like ramifications and becomes white; it gives off moisture. It is seldom that the above-described appearance of light can be observed in this variety. They both, however, behave alike with the fluxes.

It is readily dissolved by borax to a dark glass deeply colored by iron, which becomes bottle-green in the reducing flame.

It is acted on by salt of phosphorus with great difficulty. The glass acquires a tinge of iron, and the fragment becomes rounded on the edges, but remains white and opaque, so that the silica is not set free by the phosphoric acid, by which this variety of the Gadolinite is distinguished from that of Kärarfvat.

Soda dissolves it to a reddish-brown, semi-fused slag. The variety  $\beta$  fuses with soda to a bead, if the quantity of the flux is not too great. Neither variety exhibits on platina foil the least trace of manganese.

*One-third silicate of yttria, mixed with silicates of lime, glucina, and the protoxides of cerium, iron, and manganese, to all appearance in uncertain proportion and in trifling quantity, Y<sup>3</sup>Si, Gadolinite, from Kärarfvet.\**

Alone in the matrass it gives off a little water. On charcoal it burns white, and fuses in a strong heat, without swelling up, to a dark, pearl-grey or reddish, opaque glass.

It is readily dissolved by borax to a transparent glass slightly colored by iron. If the bead is saturated, the opaque glass crystallizes on cooling, and acquires a greyish tint, inclining to red or green, according to the degree of oxidation of the iron; but the enamel-like opacity which characterizes yttria cannot be obtained with the Gadolinite.

It is dissolved by salt of phosphorus, leaving a siliceous skeleton, and giving an almost colorless glass, which becomes opalescent on cooling.

<sup>1</sup> With soda it fuses with difficulty to a greyish-red slag. On platina foil it gives a trace of manganese.

\* For this examination the purest Gadolinite, having a granular fracture and yellow color, was used. It often contains a kernel of vitreous Gadolinite; both kinds of reaction are obtained, if a mixture of both varieties is used for blowpipe experimentation.

*One-third silicate of yttria, protoxide of cerium, oxides of lanthanum and didymium, alumina, lime, and the protoxides of iron and manganese*; it cannot be reduced to a determinate formula.

*Cerine*, from Bastnäs.

Alone in the matrass it gives off water, without changing its appearance; the water is not chemically combined with the mineral. It fuses readily with intumescence to a black and brilliant bead.

It is readily dissolved by borax. The glass is black and opaque, but becomes blood-red in the exterior flame, as long as it remains hot, and more or less darkly yellow on cooling; in the reducing flame it acquires a fine green tinge of iron. The bead does not become opaque by flaming.

It is decomposed by salt of phosphorus, leaving an opaque siliceous skeleton. The glass is tinged with iron while hot, but it becomes colorless and opalescent on cooling.

It dissolves with soda to a black glass, which is not rendered less fusible by the addition of more of the flux.

*Remark.* I have not had an opportunity of examining THOMSON'S Allanite before the blowpipe. It seems to behave very much like cerine.

*Orthite*, from Finbo and Gottliebsgång, and also from the granite near Stockholm and Söderköping. Orthite contains between 5 and 9 per cent. of chemically combined water.

Alone in the matrass it gives off water, and acquires a lighter color at a high temperature. On charcoal it puffs up, becomes yellowish-brown, and finally fuses, boiling violently, to a black, blebby glass.

It is readily dissolved by borax. The glass is blood-red in the oxidating flame while hot, and yellow after cooling. In the reducing flame it is colored green by iron.

It is dissolved with the usual phenomena by the salt of phosphorus.

With soda it swells up; with a very small quantity it fuses, with more it swells up to a greyish-yellow slag. On platina foil it exhibits traces of manganese.

*Pyrorthite*, ( $CS + 3AS$ ), containing one-third its weight of carbon and one-fourth its weight of water, also a considerable amount of  $ceS$ , and small quantities of  $FS$ ,  $mnS$ , and  $YS$ , from Kårarfvet.

Alone in the matrass it first gives off a large amount of water, which, towards the end of the operation, acquires a yellowish tint and smells burnt. The mineral is then coal-black. Gently heated on charcoal, and then raised at one point to a



red heat, it takes fire and continues to burn without flame or smoke. If several small fragments be placed together, or if a little heap of the pulverized mineral be used, the combustion goes on much more actively. It is rendered more lively by gentle blowing. After the combustion is finished, the mineral is white, or greyish-white; the color varies with different fragments, and sometimes inclines to red. The mineral is now so porous and light, that it cannot be made to remain upon the charcoal when the flame is directed upon it. Held in the forceps, it fuses with difficulty to a black bead with a dull surface.

With borax, it dissolves readily to a glass, which behaves like the borax glass of the preceding variety.

It is dissolved with difficulty by salt of phosphorus. The porous fragment remains on the surface of the globule as long as it continues fused, but it sinks into it as it cools. If the bead be heated again, it makes its appearance again on the surface.

It behaves with soda like orthite.

#### TITANIC ACID AND ITS SALTS.

##### *Titanic acid, Ti.\**

##### a. *Anatase*, from Oisan.

Behaves like pure oxide of titanium. In general it may be remarked, that the natural oxides of titanium dissolve with difficulty in salt of phosphorus, and that the undissolved portion looks white and opaque, like a salt mingled with the flux.

b. *Rutile* and *acicular titanium* behave like oxide of titanium, but the hyacinth color which they give in the oxidating flame is never so clear as that obtained with anatase. With soda on platina foil, the flux is colored green on its edges, a proof of the presence of manganese.

*Remark.* Rutile from Kåringbricka, often gives with the fluxes in the oxidating flame a chrome-green glass, and colors soda yellow, when fused with it in the oxidating flame. Often, on the contrary, the presence of chrome cannot be detected. It seems, therefore, to be an inconstant and varying ingredient in the mineral.

*Titanite, Spheue*, a combination of titanate and silicate of lime, in not yet accurately determined proportions.

\* For the general behavior of titanic acid in the salts of the titanium see page 62. I remark once for all, that in this and the following diagrams I shall notice the general behavior of the substance under consideration only when there is some discrepancy which deserves notice.

Alone in the matrass it gives off a small amount of water, which, however, seems to be only hygrometric moisture. The yellow variety undergoes no change; the brown turns yellow, but retains the same degree of transparency. A variety from Frugård, in Finland, exhibits the same phenomena of light as the glassy Gadolinite, but far less intensely.

On charcoal, or in the forceps, it fuses on the edges with slight intumescence to a dark glass. The unfused portion remains light yellow and semi-transparent.

It dissolves tolerably readily with borax, to a transparent, yellow glass, which becomes darker with a larger quantity of the assay; the characteristic color of titanium cannot, however, be obtained with borax.

It is slowly dissolved by salt of phosphorus; the undissolved portion becomes milk-white. In a strong reducing flame the color of titanium appears, but more readily if tin be added. If the blast be continued for a long time, the bead becomes opalescent while cooling.

It dissolves with soda to an opaque glass, which cannot be rendered transparent by any proportion of the flux. On cooling, its reaction is characteristic of the oxide of titanium. With a large portion of soda it sinks into the charcoal, and iron can be obtained by reduction.

*Titanate of zirconia, yttria, protoxides of cerium, manganese and iron, lime and other bases. Polymignite*, from Fredrikswärn.

In the matrass it does not give off water. On charcoal it undergoes no change in color or lustre, neither does it fuse.

With borax it dissolves readily to a glass colored by iron, which, with a larger portion of the assay, acquires the property of becoming opaque by flaming, when it generally acquires a color inclining to brownish-yellow. With a still larger quantity it becomes opaque on cooling. With tin the bead takes a reddish tinge, inclining to yellow.

It is not easily dissolved by salt of phosphorus; the glass has a reddish tinge in the reducing flame, which color is not changed by the addition of tin.

It is decomposed by soda, and becomes greyish-red, but does not fuse; on platina foil it exhibits traces of manganese.

*Titanate of zirconia, with protoxide of cerium, lime, and protoxide of iron. Aeschynite*, from Miask in the Ural Mts.

Alone in the matrass it gives off water, without changing its appearance. In the open tube it gives evident traces of fluoric acid.

On charcoal or in the forceps it puffs up as it begins to be

ignited, enlarges in all directions, especially in the direction of the fibres, bends to one side, remains smooth on the surface, becomes rusty-yellow, and fuses on its extreme edges to a black slag.

It is readily dissolved, and in large quantity, by borax ; the glass is dark yellow, both in the oxidating and reducing flame ; it becomes opaque by flaming, and with a large portion of the assay, of itself ; with tin, the borax glass becomes transparent and blood-red after it is perfectly cold.

It is readily dissolved by salt of phosphorus. The glass is colorless and transparent. With a large quantity of the assay it becomes pale yellow, and as long as it remains hot dark yellow ; it deposits a white, undissolved substance. In the reducing flame it acquires, especially with the aid of tin, a dirty dark brown color, which, if the operation of reduction is successful, changes to a clear color of the protoxide of titanium.

It is decomposed by soda, without fusing ; a rusty-yellow mass remains. A few globules of tin are obtained by reduction ; it gives no trace of manganese on platina foil.

*Titanate of zirconia, with two-thirds silicate of lime, magnesia, and the protoxide of iron. Oerstedine, from Arendal.*

Alone in the matrass it gives off water, without changing its appearance externally. It is infusible.

Borax dissolves it exceedingly slowly. The undissolved portion is milk-white, the glass is colorless. If pulverized, it dissolves much more readily, without leaving a residuum.

Its behavior with salt of phosphorus is the same. With tin, the reaction of titanium can be sometimes obtained ; sometimes, or rather, generally, the attempt does not succeed ; why, I am unable to say. The glass treated with tin becomes, after being strongly heated, opaque, white and crystalline, on cooling.

With soda on platina it does not dissolve ; the fused soda is yellowish, and after cooling, white, inclining to green. On charcoal, the soda sinks into the charcoal, and leaves a greyish-yellow slag. By reduction, traces of tin are obtained.

*Titanate of the protoxide of iron, at various degrees of saturation, Crichtonite, Menaccanite, Nigrine, Iserine, Ilmenite, Volcanic iron, Iron sand, and in general all varieties of magnetic iron ore with a vitreous fracture.*

Alone it remains unchanged and infusible. With the fluxes it behaves like the pure protoxide of iron ; but if it is dissolved in salt of phosphorus, and the glass reduced, after the color of the protoxide of iron has disappeared, a more or less deep shade of red makes its appearance, which is deepest at the last instant

of cooling. The depth of the color gives an idea of the amount of titanous acid present. The addition of tin brings out the characteristic color of titanium, if the amount present is considerable. If the quantity of titanium is small, the color disappears after fusion with tin. (See above, the reaction of the oxide of titanium.) With soda on platina foil, several varieties give traces of manganese.

*Remark.* If the same experiments be made with an oxide of iron which does not contain titanium, it often happens that the reduced glass, when cold, has a tinge of yellow or red, so that an inexperienced person who expects to obtain a perfectly colorless glass, may be led to suspect the presence of a small amount of titanium. As long, however, as the reaction is indecisive, this is no reason to suspect the presence of titanium.

#### TANTALIC ACID, AND SALTS OF THE TANTALATES.

*One-third tantalate of lime and yttria*, mixed with a little tungstate of the protoxide of iron,  $\left. \begin{array}{c} \text{Y}^3 \\ \text{Ca}^3 \end{array} \right\} \ddot{\text{Ta}}$ , *Dark yttro-tantalite*, from Ytterby.

*One-third tantalate of lime and yttria, with a considerable quantity of one-third tungstate of the protoxide of iron,*

$\left. \begin{array}{c} \text{Ca}^3 \\ \text{Y}^3 \\ \text{Fe}^3 \end{array} \right\} \left\{ \begin{array}{c} \ddot{\text{Ta}} \\ \ddot{\text{W}} \end{array} \right. \text{Black yttro-tantalite, from Finbo, Ytterby, and K  rarfvet; and}$

*One-third tantalate of yttria and oxide of uranium,*  $\left. \begin{array}{c} \text{Y}^3 \\ \ddot{\text{U}} \end{array} \right\} \ddot{\text{Ta}}$ ,

*Yellow yttro-tantalite*, from Ytterby and Finbo.

These various yttro-tantalites behave before the blowpipe as follows :

Alone in the matrass they give off water and become yellow, if they were black at first. Some become spotted with black, which spots do not undergo farther change. By ignition they become white, and the glass is attacked above the assay. The water colors Brazil-wood paper yellow at first, and then bleaches it.

In the forceps or on charcoal they are infusible.

Borax dissolves them to an almost colorless glass, which, on the addition of more of the flux, becomes of itself opaque.

They are dissolved by salt of phosphorus, and at first oxide of tantalum remains undissolved as a white skeleton, but with a strong heat this is also dissolved. The black yttrio-tantalite from Ytterby gives a glass which is faintly tinged with rose-red in a strong reducing flame after cooling, which is caused by the presence of tungsten. The dark and the yellow varieties from Ytterby become faintly but beautifully green on cooling, from the presence of uranium. The yttrio-tantalite from Finbo and Kårarfvet gives a deep color of iron, which conceals the characteristic color of the uranium.

They are decomposed by soda without dissolving. On platina foil they exhibit traces of manganese. By reduction with soda and borax traces of tin are obtained. The variety from Finbo, however, contains so much iron, that tin cannot be detected in this way.

*Tantalate of yttria, protoxide of cerium and zirconia. Fergusonite*, from Kikertaursak, not far from Cape Farewell in Greenland.  $\text{Y}^3\text{Ta}$ ,  $\text{Ce}^3\text{Ta}$ ,  $\text{Zr}^2\text{Ta}$ .

Alone on charcoal it gives off water, first becoming dark, and then pale, yellow. It cannot be fused on charcoal.

It is dissolved by borax with difficulty; the glass is yellow as long as it remains warm. The undissolved portion is white. The saturated glass can be rendered opaque, with a tinge of dirty yellowish-red, by flaming.

It is slowly dissolved by salt of phosphorus; the undissolved portion is white. The glass is yellow in the oxidating flame and colorless in the reducing flame, or if fully saturated it inclines to red; in this case it can easily be rendered opaque by flaming or on cooling, which is not the case with a moderate quantity of the assay.

Fused with tin, the glass of the salt of phosphorus does not become colored, but the undissolved portion inclines to flesh-red.

It is decomposed, without dissolving, by soda, and leaves a reddish slag.

Numerous globules of tin are obtained by reduction.

*Tantalate of lime, protoxides of cerium, manganese and iron, and oxide of uranium, with a small amount of titanate acid, oxide of tin and fluor. Pyrochlore*, from Fredriksvärn, Norway.

Alone it becomes clear brownish-yellow, retains its lustre, and fuses with difficulty to a dark brown, slaggy mass.

It dissolves perfectly with borax to a transparent glass, which

is reddish-yellow in the oxidating flame, and which can easily be rendered opaque by flaming. If a large proportion of the mineral be employed, the bead is converted of itself into a white enamel on cooling. In the reducing flame a dark red bead is obtained like that of ferriferous titanate acid, which can be converted into a light, greyish-blue enamel, often with stripes of clear blue, by flaming.

In the salt of phosphorus it dissolves perfectly, effervescing at first. In the oxidating flame the bead is yellow as long as it remains hot, but on cooling, generally grass-green. In the reducing flame this fine green is gradually converted into a dirty color, and after it has been subjected to the reducing flame for a short time, a bead is obtained, which has a deep red color inclining to violet, like that given by iron containing titanate acid. This color can be driven off in the oxidating flame, and the bead has then a fine grass-green color, like that given by uranium, if the heat be not too long continued. With soda on platina foil it gives traces of manganese.

*Neutral tantalate of the protoxides of iron and manganese,*  
 $\text{Fe } \ddot{\text{Ta}} + \text{Mn } \ddot{\text{Ta}}, \text{ Kimito-tantalite.}$

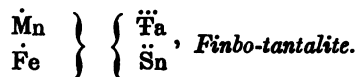
Alone it is entirely unchangeable.

It is gradually and perfectly dissolved by borax. The glass indicates only iron by its color, but it can be rendered greyish-white by flaming, at a certain degree of saturation, and it becomes of itself opaque on cooling, if still more fully saturated. The glass has while transparent a faint bottle-green color.

It is slowly dissolved by salt of phosphorus, and shows only the color of iron; the glass does not become red on cooling after being heated in the reducing flame, which proves the absence of tungstic acid.

With soda on platina foil it exhibits traces of manganese. On charcoal, with the addition of a little borax, which dissolves the tantaliferous combination and prevents the reduction of the iron, tin is obtained by reduction in the usual way.

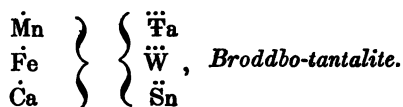
*Neutral tantalate of the protoxides of iron and manganese mixed with the stannate of the same bases,*



Behaves like the variety from Finland, but gives a considerable quantity of tin by reduction in the usual way. It

seems to contain an uncertain amount of tin, and some specimens are evidently only tantaliferous oxide of tin. The presence of tantalum can always be detected by its property of giving with borax a glass more or less faintly tinged with iron, which can be rendered enamel-like by flaming.

*Neutral tantalate of lime, protoxides of iron and manganese, with tungstates and stannates of the same bases,*



Alone it remains unchanged.

With borax it behaves like the preceding.

With salt of phosphorus it is slowly dissolved; in the oxidizing flame, with the characteristic color of iron; in the reducing flame, it acquires a red color, which deepens on cooling, and indicates the presence of tungsten. The addition of tin does not change this color, or produce the green color which is obtained with pure tungsten.

With soda it behaves like the preceding, but gives a larger quantity of tin by reduction with soda and borax.

*Two-thirds tantalate of the protoxides of iron and manganese,*



Alone it remains unchanged.

It is readily dissolved by borax to a black or deep brown, almost opaque, bottle-green glass, which cannot be rendered opaque by flaming, unless colored so deeply by iron as to be opaque; this circumstance distinguishes the basic tantalate from the neutral.

It is slowly dissolved by salt of phosphorus to a glass deeply colored by iron, in which it is not possible to detect a trace of tungsten.

With soda it gives on platina foil traces of manganese. With soda and borax it gives by reduction traces of tin.

*Addition.* Tantalite from Haddam, in Connecticut.

Behaves with borax like the variety from Bodenmais, and with salt of phosphorus like that from Broddbo, and seems to be a basic tungsteniferous tantalite.

*Oxide of tantalum combined with the protoxides of iron and manganese,*

$\begin{matrix} \text{Fe} \\ \text{Mn} \end{matrix} \left. \vphantom{\begin{matrix} \text{Fe} \\ \text{Mn} \end{matrix}} \right\} \text{Ta}^2, \text{ Tantalite with cinnamon-brown streak, from Ki-} \\ \text{mito.}$

Alone it undergoes no change.

It is so slowly dissolved by borax that it appears to be insoluble; but if the finely levigated powder be employed, it dissolves gradually, although it requires long and strong heating. The glass is not colored by peroxide of iron, but retains the dark-green color characteristic of the protoxide as long as any portion of the assay remains undissolved. This behavior depends on the insolubility of the oxide of tantalum in borax, as well as on its property of acquiring a higher degree of oxidation, so that it dissolves, and the peroxide of iron formed in the operation is reduced to the state of protoxide.

It is more readily dissolved by the salt of phosphorus, and behaves in this respect like the Kimito-tantalite.

It is decomposed by soda without being dissolved; by reduction in the usual manner it gives tin, and on platina foil the reaction of manganese.

#### OXIDES OF ANTIMONY.

*Oxide of antimony,  $\text{Sb}^{\text{III}}$ , White antimony,* behaves exactly like the artificially prepared oxide (page 60).

*Oxysulphuret of antimony,  $\text{Sb}^{\text{III}} + 2 \text{Sb}^{\text{IV}}$ , Red antimony, (Rothspiesglanzerz,) behaves like the sulphuret of antimony (page 108).*

*Antimonious acid,  $\text{Sb}^{\text{III}}$ , formed from sulphuret of antimony.*

Alone in the matrass it gives off water, and is, therefore, hydrous antimonious acid. On charcoal it is not reduced, but it coats the charcoal with a trifling deposit of antimony. With soda it is reduced to the metallic state. When the globules collect and volatilize, it can be seen whether the acid is pure or not.

#### TUNGSTIC ACID AND SALTS OF THE TUNGSTATES.\*

*Tungstic acid,  $\text{W}^{\text{VI}}$ , from Connecticut,* behaves exactly like the artificially prepared tungstic acid.

\* The general behavior of tungstic acid in the salts of the tungstates will be found on page 57.

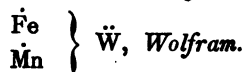


*Tungstate of lime, Ca W̄, (Schwerstein.)*

Alone in the matrass it suffers no change. On charcoal it fuses on its thin edges, at a high temperature, to a semi-transparent glass. It is readily dissolved by borax to a transparent glass which quickly becomes opaque, milk-white and crystalline; it does not become colored by the reducing flame, even with the addition of tin.

It is readily dissolved by salt of phosphorus to a glass which is transparent and colorless in the exterior flame; in the interior flame the glass is green, as long as it remains hot, and has a fine blue color on cooling. If tin be added, the glass acquires a deeper color and becomes green. If the blast be continued for a long time, and a sufficient quantity of tin be added, the tungsten is precipitated, and finally only a faint greenish tinge remains.

With soda it forms a swollen, white slag, rounded on the edges.

*Tungstite of the protoxides of iron and manganese,*

Alone in the matrass it sometimes decrepitates and gives off a little moisture. On charcoal it can be fused, by a strong heat, to a globule, of which the surface is a collection of tolerably large, foliated, iron-grey crystals, having a metallic lustre. If only a portion of the assay is fused the surface is but slightly crystalline.

It is somewhat readily dissolved by borax, and gives the color of iron, but so that no conclusion can be made as to the presence of tungstic acid from the play of colors.

It is readily dissolved by the salt of phosphorus. In the oxidizing flame the bead is colored by iron only, but in the reducing flame it becomes deep red. With a very trifling quantity of the mineral it becomes opaque, so that only a minute amount is required to produce a distinct reaction. If tin be added and the whole heated for a moment, the color becomes green. This succeeds better when the color is not too intense, since in this case it is generally so dark as to render the glass opaque. If the assay be heated for a sufficient length of time in a strong reducing flame, the tungsten is entirely reduced by the tin, and the green color disappears and leaves a faint red, which afterwards undergoes no farther change.

It is dissolved by soda on platina foil and crumbles. The soda exhibits on its edges the color of manganese. On char-

coal it is readily reduced to tungstate of iron, which can be separated by washing.

*Remark.* Wolfram has sometimes the property of decrepitating strongly and exfoliating. It is then generally covered with a yellow, earthy, rather hard crust. This crust, which might easily be mistaken for tungstic acid, is arseniate of iron, and wolfram itself gives, when treated in the reducing flame, a strong odor of arsenic.

*Tungstate of lead*,  $Pb\ W_2$ , from Zinnwald.

Alone on charcoal it fuses and gives off fumes of lead, leaving a dark, crystalline bead, which looks metallic, but gives a light grey powder.

It is dissolved by borax in the outer flame, without color. In the interior flame it acquires a yellowish tint, and becomes grey and opaque as it cools. With a stronger heat the lead is volatilized, and the bead becomes transparent and dark red after cooling, as if from pure tungstic acid.

With the salt of phosphorus it dissolves in the exterior flame to a colorless glass; in the interior flame it is transparent and blue, but the color is not so pure as that which pure tungstic acid gives. If a larger quantity be added the glass acquires a greenish tinge, and finally becomes opaque.

With soda it gives a quantity of globules of lead.

*Vanadate of lead*, from Matlock, decrepitates in the matrass, and fuses with difficulty on platina foil. The platina becomes coated with a thin crust of fused salt, which surrounds the still unmelted, slaggy mass.

On charcoal it fuses to a bead, which is soon absorbed by the charcoal, leaving globules of lead on the surface. The lead can be entirely volatilized.

Borax gives on platina a transparent glass, which is dark yellow while hot, and colorless when cold. On charcoal a greenish glass and globules of lead are obtained.

Salt of phosphorus dissolves it on platina to a dark yellow glass, which when cold is light yellow. In the reducing flame the color is deeper, and acquires a greenish tint on cooling. On charcoal a green glass is obtained.

Soda dissolves it on platina to a clear yellow liquid, which resembles fused oxide of lead, after cooling. On charcoal vanadate of soda is obtained, which sinks into the charcoal, leaving globules of lead on the surface. The charcoal containing soda does not give on silver traces of sulphur.

With salt of phosphorus and oxide of copper the flame is not colored, as it would generally be if chlorine was present.

With boracic acid and iron distinct traces of the presence of phosphoric acid are obtained.

*Basic vanadate of lead with basic chloride of lead, from Zimapan.* ( $\text{Pb}^2 \ddot{\text{V}}$ ,  $\text{Pb} \ddot{\text{C}} + 2 \text{Pb}$ .)

It behaves like the preceding, with this difference, that it emits a strong odor of arsenic when treated with soda on charcoal. With boracic acid and iron, on the contrary, it does not give a phosphuret of iron. Neither can the presence of chlorine be detected by the salt of phosphorus and oxide of copper.

#### MOLYBDIC ACID AND ITS SALTS.

*Molybdic acid,  $\ddot{\text{Mo}}$ , from Bispberg.*

The yellow coating on the sulphuret of molybdena, behaves like pure molybdic acid, but when treated with soda it is absorbed by the charcoal, and leaves oxide of iron on the surface.

*Molybdate of lead,  $\text{Pb} \ddot{\text{Mo}}$ , (Gelbbleierz,) from Bleiberg.*

Alone it decrepitates violently and acquires a darker yellow color, which disappears again on cooling. On charcoal it fuses and sinks into the charcoal, leaving a quantity of reduced lead on the surface. If the substance absorbed by the charcoal be collected and washed, a mixture of malleable globules of lead and of metallic molybdena, or molybdate of lead, is obtained; the latter has a metallic lustre, but is not malleable or fusible.

It is readily dissolved by borax in the exterior flame into a slightly colored glass. In the interior flame a transparent glass is obtained, which becomes suddenly dark and opaque as it cools. If flattened in the forceps it is seen to have a brownish color.

It is readily dissolved by salt of phosphorus. A small quantity of the assay gives a greenish glass, like that obtained with molybdic acid alone. With a larger portion, a black opaque glass is obtained.

It is dissolved by soda, and the mass sinks into the charcoal, leaving reduced lead on the surface.

## OXIDES OF CHROME AND SALTS OF THE CHROMATES.\*

*Sesquioxide of chrome*,  $\ddot{\text{Er}}$ , *Chrome ochre*, a mechanical mixture of  $\ddot{\text{Er}}$  with quartz and transition rocks, from the Dept. Saone et Loire, in France.

Alone it loses its color and becomes almost white; it does not fuse, but exhibits a slaggy surface, which, under the microscope, looks as if it were made up of vitrified and infusible particles.

The oxide of chrome is taken up by borax, and the bead has a fine green color. The fragment of mineral becomes white, and dissolves with difficulty.

It is quite as difficultly dissolved by the salt of phosphorus. The glass, with an equal quantity of the mineral, is less strongly colored than the borax glass.

It is dissolved by soda, but with difficulty, and a large quantity of soda is requisite. The glass is, even while fused, opaque, and on cooling has the appearance of a dirty, greyish-green enamel.

*Remark.* The chrome ochre from Elfdalen, which, in all probability, occurs in a spathic albite, behaves in the same manner, with only such difference as is caused by the nature of the gangue. In the same way behaves the chromiferous clay of Mårtanberg, with this exception, that the whole mass fuses, in a strong heat, to a black slag.

*Wolkonskoite*, a basic silicate of alumina, oxide of chrome and peroxide of iron, from Perm.

In the matrass it gives off a large quantity of water. The green color inclines to brown.

In the forceps it exhibits on the extreme edges traces of a slag, bursts upon the surface, becomes brown, and does not fuse.

Borax and salt of phosphorus dissolve it very imperfectly, with the play of colors of the oxide of chrome. The undissolved portion is black.

With soda it fuses on charcoal to a bead with effervescence. The bead when cool is spotted with green and yellow. On platina it gives chromate of soda, which liquefies, and leaves an undissolved dark red mass.

\* For the general behavior of chromic acid in the salts of the chromates, see page 58.

*Combination of the sesquioxide of chrome and the protoxide of iron,  $\dot{\text{F}}\ddot{\text{E}}\ddot{\text{r}}$ , sometimes mixed with more or less of the aluminate of the protoxide of iron,*

$\dot{\text{F}}\text{e} \left\{ \begin{array}{c} \ddot{\text{E}}\ddot{\text{r}} \\ \ddot{\text{A}}\text{l} \end{array} \right.$ , and sometimes oxidized to  $\ddot{\text{F}}\text{e}\ddot{\text{E}}\ddot{\text{r}}$ , *Chromic iron*,  
from various localities.

Alone it undergoes no change, except that the varieties, which were not originally attractable by the magnet, become so when heated in the reducing flame.

It is slowly but perfectly dissolved by borax and the salt of phosphorus. The color of the iron, which varies in the exterior and interior flames, appears only while the assay is hot, and when it disappears on cooling, the fine green color of the oxide of chrome makes its appearance. This is more distinct when the assay is treated in the reducing flame, and is most beautiful when it is fused with tin.

It is not attacked by soda, and does not color that flux when fused with it on platina foil. By reduction on charcoal, iron is obtained.

*Chromate of lead,  $\text{Pb}\ddot{\text{C}}\text{r}$ , (Rothbleierz,) from Siberia.*

Alone it decrepitates, and splits in the direction of the crystalline structure, acquires a deeper color, which disappears on cooling, fuses on charcoal and spreads itself out, while the inferior portion is reduced, giving fumes and the flame of lead. The upper portion is a dark mass, which gives a reddish-brown powder, and which cannot be made green by heating.

It is readily dissolved by borax. A small quantity of the assay colors the glass green; a larger portion gives a green glass, but so filled with dark colored particles that it appears opaque. In the reducing flame it acquires a darker color, and has, after cooling, the appearance of a greenish-grey enamel.

It is readily dissolved by salt of phosphorus to a fine green glass. With a larger quantity of the flux it becomes, on cooling, opaque and grey, or greyish-green.

With soda on charcoal it gives a globule of lead, and the mass sinks into the charcoal. On platina it gives, in the oxidating flame, a dark yellow, fused mass, which becomes lighter on cooling. In the reducing flame the fused mass is green.

*One-third chromate of the oxides of lead and copper.*

$\dot{\text{C}}\text{u}^3\ddot{\text{C}}\text{r}^2 + 2\dot{\text{P}}\text{b}^3\ddot{\text{C}}\text{r}^2$ , *Vauquelinite*, from Siberia.

Alone in the matrass it does not give off water. On char-

coal it swells up a little and then fuses, with violent frothing, to a dark grey bead, having a metallic lustre, and in which small globules of reduced metal are seen. The greater portion of the bead remains unaltered, even in the strongest reducing flame.

Borax dissolves a small quantity of the mineral with effervescence to a green glass, which, treated in the exterior flame, remains transparent after cooling, but after being strongly heated in the reducing flame, after cooling it becomes red, opaque red, or quite black, according to the quantity of the mineral in the bead. The red color, which is occasioned by copper, is still more distinct if tin be added. If a large quantity of the mineral be added at once, the glass becomes black immediately.

Its behavior with the salt of phosphorus is the same.

It is dissolved by soda with effervescence. On the platina wire it gives in the oxidating flame a transparent, green glass, which becomes yellow and opaque on cooling. If a drop of water be added it acquires a yellow color from the alkaline chromate. It is absorbed by charcoal, and gives, after washing, metallic lead.

#### BORACIC ACID AND SALTS OF THE BORATES.\*

*Boracic acid*,  $\ddot{\text{B}} + 3 \ddot{\text{H}}$ , from Sasso in Tuscany. (Moistened with water and placed on Brazil-wood paper, it discharges its color after half an hour. Moistened with alcohol, it colors turmeric paper brown.)

Alone on charcoal it fuses to a transparent glass. If it contains sulphate of lime, the bead becomes opaque as it cools.

*Biborate of soda*,  $\ddot{\text{Na}} \ddot{\text{B}}^2 + 10 \ddot{\text{H}}$ , mixed with a combustible organic substance, *Tincal*.

It puffs up like borax, becomes carbonized, smells burnt, and fuses to a bead. With fluor spar and bisulphate of potash it colors the flame around and before the powder beautifully green, which is also the case with all the minerals mentioned under this division.

*Borate of magnesia*,  $\ddot{\text{Mg}}^2 \ddot{\text{B}}^2 = \ddot{\text{Mg}} \ddot{\text{B}}^2 + 2 \ddot{\text{Mg}} \ddot{\text{B}}$ , *Boracite*, from Lüneberg.

\* For the general reaction of boracic acid in the salts of the borates, see page 86.

Alone in the matrass it remains unchanged. On charcoal it fuses and swells; it is difficult to obtain a transparent bead; it crystallizes on cooling, so that the whole surface becomes covered with acicular crystals. The glass is yellowish while hot, but becomes white and opaque on cooling.

It is readily dissolved by borax to a transparent glass colored by iron.

Salt of phosphorus dissolves it readily to a transparent glass, which can be rendered opaque by flaming, and which, with a larger quantity of the assay, becomes opaque of itself on cooling.

It is dissolved by soda. If exactly the proper quantity of this flux is used, so that a transparent glass is obtained, it crystallizes with large facets on cooling, quite as beautifully as the phosphate of lead. With a larger portion of soda a transparent glass is obtained, which is no longer crystalline, and in reality is nothing more than a solution of magnesia in glass of borax.

*Borate of lime with borate of magnesia*,  $\text{Ca}^3 \ddot{\text{B}}^4 + \text{Mg} \ddot{\text{B}}^4 + 18 \text{H}$ , *Hydroboracite*, from the Caucasus.

In the matrass it gives off a large quantity of water, and becomes milk-white.

In the forceps it fuses with slight intumescence to a transparent glass.

It gives readily with borax and salt of phosphorus a transparent glass.

With a little soda, it gives a transparent glass. With more, the bead becomes milk-white and crystalline as it congeals. With still more, it spreads out on the charcoal, and becomes white and crystalline as it cools.

*Borate and bisilicate of lime*,  $\text{Ca}^3 \ddot{\text{Si}}^4 + 3 \text{Ca} \ddot{\text{B}} + 3 \text{H}$ ,  $(\text{C} \text{S}^4 + \text{C} \text{B}^3 + \text{Aq})$ , *Datholite*, and

$\text{Ca}^3 \ddot{\text{Si}}^4 + \text{Ca} \ddot{\text{B}} + 6 \text{H}$ ,  $(\text{C} \text{S}^4 + \text{C} \text{B}^3 + 2 \text{Aq})$ , *Botryolite*, both from Arendal, behave alike, and in the following manner:

Alone in the matrass they give off water. On charcoal they swell up a little, like borax, and fuse to a transparent glass, which is colorless, faint rose-red, or iron-green, according to the degree of purity and color of the assay.

They are readily dissolved by borax to a transparent glass, which is either colorless, or tinged with the above-mentioned colors.

They are dissolved by salt of phosphorus, leaving a siliceous

skeleton; a larger quantity of the assay gives a glass which becomes opaque, and, finally, enamel-white.

With a small quantity of soda they dissolve to a transparent glass. With more, the glass becomes opaque on cooling; with still more, the whole is absorbed by the charcoal.

With gypsum they fuse, but less readily than fluor spar; the bead remains transparent after cooling.

With the solution of cobalt an opaque, blue glass is obtained.

*Silicates of several bases, with one or more borates in trifling quantity, in regard to which it is not known how far they exist in the mineral as essential ingredients.*

*Tourmaline, K, L, Na, Mg, Fe, Al, Si, B.*

a. *Potash tourmaline, Schorl.*

α. *Black tourmaline, from Kåringbricka.*

Alone in the matrass it does not give off water. On charcoal it fuses, and swells up considerably, becoming white. The swollen mass fuses with difficulty to a semi-transparent bead of a greyish-yellow color.

It is readily dissolved by borax, with effervescence, to a transparent glass, which exhibits a faint tinge of iron while it remains hot.

It is readily dissolved by borax with considerable effervescence; it leaves a skeleton of silica, and the bead becomes opalescent.

It forms with soda with great difficulty a very infusible glass, which becomes still more infusible on the addition of more soda.

β. *Black tourmaline, from Bovey in England.*

Alone it swells up, and then collapses into a black, infusible, slaggy mass. It behaves with the fluxes like the preceding.

γ. *Green tourmaline, from Brazil.*

Alone it intumesces, becomes black and vitreous, without fusing entirely, and gives, after being strongly heated, a rounded, yellowish, blebby slag.

It is dissolved by borax with considerable facility; at first it effervesces a little. The glass is slightly tinged by iron, and white globules remain undissolved and swim about in it for a long time.

It behaves like the preceding variety with salt of phosphorus.

The same is true with soda, except that it sometimes gives a more fusible glass. On platina foil it does not exhibit traces of manganese.



b. *Lithia (and soda) tourmaline, Rubellite, Tourmaline apyre.*

a. *Red and light green variety.*

Alone it becomes milk white, swells up, and becomes fractured transversely; it does not fuse, but becomes slaggy on the surface.

With borax it effervesces a little at first, then becomes milk-white, and dissolves slowly and difficultly to a transparent, colorless glass.

With salt of phosphorus it effervesces slightly, becomes milk-white, remains entire, dissolves slowly and with difficulty, the fragment gradually diminishing in size; the glass is opalescent on cooling.

With soda it fuses with the greatest difficulty to an opaque glass. On platina foil it becomes dark green.

β. *Light blue, finely radiated variety.*

Alone it swells up a little and becomes white, but does not fuse, but becomes slaggy on the surface and blebby in the interior, where the heat is the strongest.

It is dissolved by borax with considerable facility, especially if a small quantity of the mineral is employed; it effervesces. The glass is transparent.

It swells up with effervescence in salt of phosphorus, and the silica skeleton becomes divided. A large portion of it redissolves. The bead becomes opalescent on cooling.

With soda it forms a dark glass, of which the fusibility is diminished, but not destroyed, by a larger quantity of soda. On platina foil it exhibits traces of manganese.

γ. *Dark blue variety in large crystals, Indicolite.*

Alone it swells up exceedingly, especially longitudinally, so that it acquires nearly three times its former length, till it bends on one side and curls together; it becomes black and slaggy.

It behaves like the preceding variety with the fluxes.

*Remark.* The varieties described under β and γ seem to be a mixture of lithia tourmaline with potash tourmaline.

*Axinite, Ca, Fe, Mn, Al, Si, B, (Thumerstein,) from Dauphiny.*

Alone it fuses with intumescence, and readily, to a dark green glass, which in the exterior flame is rendered black by superoxide of manganese.

It is readily dissolved by borax. The glass is colored with iron, but can be made in the exterior flame to take an impure amethystine tinge.

It is decomposed by the salt of phosphorus like the other varieties.

It becomes green with soda at first, and then fuses to a black glass, which has an almost metallic lustre.

On platina foil it gives decided traces of manganese.

TURNER asserts that he obtained a flame tinged green by boracic acid, by the aid of sulphate of ammonia and fluor-spar.

#### CARBONIC ACID AND THE CARBONATES.

*Carbonate of soda*,  $\text{Na}_2\text{CO}_3 + 10\text{H}$ , and  $\text{Na}_2\text{CO}_3 + 4\text{H}$ , *Soda and Trona*, exhibit the usual reaction of soda used as a flux. The presence of the alkalies is determined as described on page 48-50.

*Carbonate of baryta*,  $\text{BaCO}_3$ , *Witherite*, see baryta, page 50.

*Carbonate of strontian*,  $\text{SrCO}_3$ , *Strontianite*, see page 51.

*Carbonate of lime*,  $\text{CaCO}_3$ .

##### a. *Calcareous spar*.

Alone in the matrass it does not give off water. On charcoal it becomes caustic, and emits a peculiar light, as soon as the carbonic acid has been entirely driven off. It becomes heated with water, and has an alkaline reaction on reddened litmus-paper. Calcareous spar containing iron and manganese blackens by burning. It behaves with the fluxes, in which it dissolves with effervescence, like pure lime. The varieties containing iron and manganese give a colored glass.

##### b. *Arragonite*.

Alone in the matrass it does not change at first, even at a temperature far above the boiling-point of water, but near a red heat it swells up, and crumbles to a white, coarse and light powder, while a small quantity of water collects in the neck of the matrass, but less than is obtained from many minerals which contain only water of decrepitation. It behaves like the preceding variety with the fluxes.

*Carbonate of soda and lime*,  $\text{CaCO}_3 + \text{Na}_2\text{CO}_3 + 6\text{H}$ , *Gay-Lussite*, from Lagunilla near Menda, in America.

Alone in the matrass it decrepitates slightly, gives off considerable water, and has an alkaline taste and reaction on test paper.

With the fluxes it behaves like carbonate of lime.

*Carbonate of baryta and lime,  $\text{Ba}\ddot{\text{C}} + \text{Ca}\ddot{\text{C}}$ , Barocalcite, from Cumberland.*

Alone in the matrass it gives off moisture. In the forceps or on charcoal it does not fuse, but burns alkaline, and when moistened with water and placed on silver foil, it gives a stain of sulphuret of silver, which is darker colored when the reddish incrustation on certain crystals has not been removed before heating the mineral.

It is readily dissolved by borax with strong effervescence. The glass acquires, on cooling, a hyacinth color (due to hepar), which can be driven off by heating in the oxidating flame.

When the borax bead has taken up an equal volume of the mineral, it becomes opaque on cooling.

Salt of phosphorus dissolves it readily and in large quantity with effervescence, to a transparent glass, which becomes opaque on the addition of a very large quantity of the mineral.

It is decomposed by soda; the greater portion is absorbed by the charcoal, but a brownish-yellow slag remains. The mass is slightly hepatic.

*Carbonate of magnesia,  $\text{Mg}\ddot{\text{C}}$ .*

a. *Magnesia marble*, from Hoboken, and

b. *Magnesite*, from various localities.

Alone in the matrass it yields little or no water. On charcoal it cracks a little and shrivels together; afterwards it has an alkaline reaction on moistened test-paper.

With borax, salt of phosphorus, soda and the solution of cobalt, it behaves like magnesia.

c. *Hydrous crystallized carbonate of magnesia,  $\text{Mg}\ddot{\text{C}} + 6\text{H}$* , from Hoboken, yields water when heated in the matrass, and behaves in general like the preceding varieties with the fluxes.

*Carbonate of lime and magnesia,  $\text{Ca}\ddot{\text{C}} + \text{Mg}\ddot{\text{C}}$ , also  $\left. \begin{array}{l} \text{Ca} \\ \text{Mg} \end{array} \right\} \ddot{\text{C}}$ , Bitter spar*, behaves before the blowpipe exactly like carbonate of lime without magnesia.

*Carbonate of the protoxide of manganese,  $\text{Mn}\ddot{\text{C}}$* , mixed with  $\text{Ca}\ddot{\text{C}}$  and  $\text{Fe}\ddot{\text{C}}$ , from Freiberg.

Alone in the matrass it yields water and decrepitates violently. More strongly heated the carbonic acid is driven off, and the assay acquires a greenish-grey color, which is due to the manganese. In a matrass with a large bulb, or on charcoal, it

is blackened by the oxidation of the protoxide. In the reducing flame on charcoal it becomes dark brown, and then reacts on Brazil-wood paper on account of the caustic lime which it contains. It then behaves with the fluxes like the oxide of manganese contaminated by iron.

*Carbonate of the protoxide of iron, Fe C̄, generally mixed with Ca C̄ + Mn C̄, Spathic iron, Brown spar.*

Heated in the matrass it yields no water. Some kinds decrepitate violently. Very gently heated it burns brown and gives a protoxide of iron, which is strongly attracted by the magnet.

*Carbonate of zinc, Zn C̄, Calamine, (Galmei.)*

Alone it gives off no water, but burns enamel-white, and then behaves like pure oxide of zinc.

*Remark.* When this mineral contains cadmium it deposits a dark yellow or red ring on charcoal, when first acted on by the reducing flame. This is best seen after the charcoal has become entirely cold. (See oxide of cadmium, page 68.)

*One-half carbonate of zinc with hydrate of zinc, Zn C̄ H̄ + 2 Zn H̄, Zinc bloom, (Zinkblüthe,) from Bleiberg and East India.*

Alone in the matrass it yields no water, and behaves like the oxide of zinc. It can be volatilized by continued heating in the reducing flame, and then gives a small slaggy residuum, which, tested by the fluxes, is found to contain iron.

*Carbonate of zinc and copper, from Siberia.*

Alone in the matrass it gives off water and changes from green to black; it gives with the fluxes the reaction of copper, but the beads are rendered opaque on cooling by oxide of zinc.

The process of reduction with soda gives a grain of copper, and the coal becomes coated with fumes of zinc.

*Carbonate of the protoxide of cerium, Ce C̄, from Bastnäs, near Riddarhyttan. It also contains the oxides of lantanium and didymium.*

Alone in the matrass it gives off moisture and burns brownish-yellow. With the fluxes it gives the reaction of the oxide of cerium.

*Carbonate of lead, Pb C̄, White lead, (Weissbleierz,) from Alstonmoor.*

It behaves like pure oxide of lead, except that it decrepitates violently, and that its white color is changed to yellow by the action of heat.

*Neutral carbonate and hydrate of copper*,  $\text{Cu} \ddot{\text{H}} + 2 \text{Cu} \ddot{\text{C}}$ , *Azurite*, (Kupferlasur,) from Chessy, Maguska, and other localities, and

*One-half carbonate of copper*,  $\text{Cu}^2 \ddot{\text{C}} + \ddot{\text{H}}$ , *Malachite*. Both behave alike. In the matrass they yield water and become black. On charcoal they first fuse, and then become reduced to metallic copper; they behave like pure oxide of copper.

#### ARSENIOUS ACID AND THE ARSENIATES.

*Arsenious acid*,  $\ddot{\text{As}}$ , *White arsenic* behaves as described on page 55.

*Arsenate of lime*,  $\text{Ca}^2 \ddot{\text{As}} + 6 \ddot{\text{H}}$ , and  $\text{Ca}^2 \ddot{\text{As}} + 4 \ddot{\text{H}}$ , *Pharmacolite*, *Haidingerite*.

Alone in the matrass it yields a large quantity of water, which has not an acid reaction; arsenious acid does not sublime. The assay loses its transparency like an efflorescent salt, but retains its form. In the forceps, if heated in the exterior flame, it fuses to a white enamel; but on charcoal, in the interior flame, it emits the odor of arsenic, and fuses more readily to a semi-translucent globule, which sometimes has a color inclining to blue, if the pharmacolite, as is often the case, is mixed with arseniate of cobalt.

With borax and salt of phosphorus it behaves like lime or the salts of lime and the volatile acids, but as it dissolves it emits a strong odor of arsenic.

It is decomposed by soda, emitting copious fumes of arsenic, and lime remains on the charcoal.

#### *Arsenate of the protoxide of iron.*

a. *Scorodite*, from Graul near Schwarzenberg; its formula is not yet known.

Alone in the matrass it first gives off water and becomes whitish-grey or yellowish. At a higher temperature it gives off white arsenic, which sublimes in small, white, brilliant crystals; the residuum becomes black. After cooling it is spotted with dark green and red, but gives a light greyish-yellow pow-

der. On charcoal it emits copious fumes of arsenic, and fuses in the reducing flame to a grey slag with a metallic lustre, which is attracted by the magnet, and dissolved by the fluxes, with which it gives the characteristic reaction of iron, while the glass emits a strong arsenical odor.

b. *Neutral arseniate of the protoxide of iron with basic arseniate of the peroxide of iron*,  $\text{Fe}^{\text{As}} + 2\text{Fe}^{\text{As}} + 12\text{H}$ , from Antonio Pereira, near Villa Rica in Brazil.

In the matrass it gives off water and becomes yellow, without changing its form. At a higher temperature it does not yield a sublimate of arsenious acid. With the fluxes it behaves like the preceding.

c. *Cube ore*, (Würfelerz,)  $\text{Fe}^{\text{As}} + \text{Fe}^{\text{As}} + 18\text{H}$ , from Cornwall.

Alone in the matrass it yields water and becomes red. With a stronger heat it yields little or no white arsenic, puffs up a little, becomes red on cooling, and gives a red powder. On charcoal and with the fluxes it behaves like scorodite.

*Basic arseniate of cobalt*,  $\text{Co}^{\text{As}} + 6\text{H}$ , *Cobalt bloom*, (Kobaltblüthe,) from Schneeberg.

Alone in the matrass it yields water and acquires a darker color, but gives no sublimate.

On charcoal it fumes strongly, emits an arsenical odor, and fuses in a strong reducing flame to arseniuret of cobalt.

With the fluxes it gives a blue glass.

*Arsenite of cobalt*, (pulverulent,) from Schneeberg.

It yields when heated in the matrass or open tube a large quantity of arsenious acid, and then behaves like the preceding.

*One-half arseniate of nickel*,  $\text{Ni}^{\text{As}} + 9\text{H}$ , *Nickel ochre*, from Allemont, (in powder, color white inclining to green.)

Alone in the matrass it yields water and acquires a darker color.

On charcoal it smells strongly of arsenic, and can be fused in the exterior flame to a metallic globule containing arsenic.

With the fluxes it behaves like oxide of nickel, but gives evidence of the presence of a large amount of cobalt when the glass is reduced.

*Arseniate of copper*, various specimens from Cornwall. T

analyses of this mineral are not yet sufficiently accurate to allow of its formula being calculated.

Arsenate of copper behaves in general with the fluxes like the oxide of copper, but smells strongly of arsenic when ignited, and gives on reduction, either alone or with soda, a white, brittle, metallic globule.

a. The greyish-green variety, in capillary crystals, when treated alone in the matrass, yields no water and undergoes no change. On charcoal at the moment of decomposition it is reduced with detonation, and is absorbed by the charcoal, when a white, metallic grain is obtained, which becomes red on cooling. The red color is due to a thin envelope of the red oxide of copper; the grain is white in the interior, and cracks under the hammer.

b. The dark green, crystallized variety behaves nearly in the same manner, but, if carefully examined, it will be seen to have deposited a fused slag around the reduced grain of metal; if lead be added, and the fused metal be thrown off from the charcoal after the slag has congealed, and this slag (which readily remains spread out upon the surface of the charcoal) be fused again, phosphate of lead is obtained, which is white, and crystallizes at the moment of congelation.

c. The green, compact, internally slightly blebby variety, behaves in the same way, but gives with lead a larger quantity of the phosphate.

d. The beautiful, light-blue, crystallized variety, yields a large quantity of water when heated in the matrass, fuses imperfectly, and is not reduced with detonation, but leaves a slaggy mass, in which white, metallic globules are seen. It does not give traces of iron with the fluxes.

*Remark.* The last mentioned variety contains, therefore, besides oxide of copper, still another base, which cannot be reduced, and which consists, according to Count WACHTMEISTER, of 8 per cent. of alumina. A portion of  $\ddot{\text{As}}$  is replaced by  $\ddot{\text{P}}$ .

#### PHOSPHORIC ACID AND THE PHOSPHATES.\*

*One-half phosphate of yttria,  $\ddot{\text{Y}}^3 \ddot{\text{P}}$ , from Lindesness, in Norway.*

\* For the common test for phosphoric acid in all the phosphates, see 84.

In the matrass it yields no water, and does not fuse on charcoal.

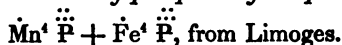
It is slowly dissolved by borax to a colorless glass, which is rendered milk-white by flaming, and with a larger quantity it becomes opaque on cooling.

It is very slowly dissolved by the salt of phosphorus, by which it is distinguished from the phosphate of lime. The glass is colorless.

It is decomposed by soda with effervescence into a light grey, infusible slag.

With boracic acid and iron it gives, like all the other salts of the phosphates here described, a regulus of phosphuret of iron.

*One-half phosphate of the protoxides of manganese and iron,*



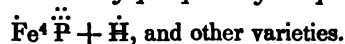
Alone in the matrass it yields a little water, which has an acid reaction on litmus paper, and tinges Brazil-wood paper yellow. It does not attack the glass. If treated in the open tube, however, it gives faint traces of fluoric acid. The water deposited in the tube does not react on Brazil-wood paper. On charcoal it fuses very readily and with strong effervescence to a black bead having a metallic lustre, which is strongly attracted by the magnet.

It is readily dissolved by borax. In the oxidating flame it exhibits traces of manganese, and in the reducing flame, of iron.

It is very readily dissolved by the salt of phosphorus. It hardly exhibits any other color than that of iron; however, by long oxidation at a low red heat a faint trace of the characteristic color of manganese may be obtained.

It is not dissolved by soda on charcoal, but gives by reduction a large quantity of iron. On platina foil it has the usual reaction of manganese.

*One-half phosphate of the protoxide of iron,  $\text{Fe}^{\cdot\cdot}\ddot{\text{P}} + 6 \text{H}$ ,*



Alone in the matrass it gives off a large amount of water, intumesces, and becomes spotted with grey and red. On charcoal it swells up, burns red, and then fuses very readily to a steel-grey bead, which has a metallic lustre. With borax and salt of phosphorus it behaves like the peroxide of iron.

With soda on charcoal it gives in the reducing flame mag-



netic grains of iron. On platina foil it does not give traces of manganese.

*Basic phosphate of copper.*

a. From Ehrenbreitstein,  $\text{Cu}^3 \ddot{\text{P}} + 5 \text{H}$ , and

b. From Libethen,  $\text{Cu}^4 \ddot{\text{P}} + 2 \text{H}$ .

Alone it does not color the flame; it crumbles to powder when rapidly heated, but remains entire if gradually warmed; it becomes black and fuses, retaining its dark color and forming a bead, in which a small globule of metallic copper is visible. This globule of copper emits a brilliant light, or flashes, at the moment of its congelation, as is the case with gold or silver, if not perfectly purified.

With salt of phosphorus and borax it behaves like pure oxide of copper.

Its behavior with soda is peculiar. A small quantity of that flux gives a liquid bead. If more soda be added, the mass intumesces for a moment, but then fuses again; and thus, each time that a fresh portion of soda is added, it swells up in the same way before fusing, till at last it forms a swollen, infusible mass. With a very large amount of soda the saline mass is absorbed by the charcoal, leaving the copper on the surface.

The most characteristic reaction of this salt is obtained by adding a quantity of metallic lead about equal in volume to the fused assay. The mass is then to be fused in an intense flame, by which all the copper is separated in the metallic form, and around the metallic bead a fused mass of phosphate of lead is obtained, which crystallizes on cooling. If, after the flux has congealed, the more fusible metal containing lead be removed, and the flux be then remelted, the bead acquires a globular shape, and the crystalline facets are considerably larger.

*Basic phosphate of alumina.*

a. *Wavellite*,  $\text{Al F}^3 + 3 \ddot{\text{Al}}^4 \ddot{\text{P}}^3 + \text{H}^{18}$ , from Barnstaple, Amberg in der Pfalz, Bohemia.

Alone in the matrass it yields water; the last drops are acid, and gelatinous with silica; they tinge Brazil-wood paper yellow. The glass after being allowed to dry becomes clouded by a deposition of silica. A ring of silica deposits above the assay, when it is ignited.

On charcoal it swells up, loses its crystalline form, and becomes snow-white.

With borax, salt of phosphorus and soda it behaves like pure alumina.

b. *Lazulite*,  $\ddot{\text{Al}}^{\ddot{\text{P}}}$ , with  $\text{Mg}^{\ddot{\text{P}}}$  and  $\text{Fe}^{\ddot{\text{P}}}$ , in various proportions, from Rödelgraben and Krieglach.\*

Alone in the matrass it gives off water, and loses its color.

On charcoal it intumesces, and acquires a blebby, vitreous appearance where the heat is the strongest, but does not fuse.

Borax dissolves it into a transparent, colorless glass.

With salt of phosphorus it becomes transparent on the edges, and gradually fuses to a transparent, colorless glass.

With soda it intumesces, but does not dissolve or fuse.

With the solution of cobalt it gives a fine blue.

c. *Calaité*, *Turquoise*, from Persia. A mixture of phosphate of alumina with phosphate of lime and silica, colored green or greenish-blue by carbonate of copper and hydrate of the oxide of copper.†

Alone in the matrass it gives off water, flies in pieces and decrepitates violently, even if very slowly heated. The water does not react on Brazil-wood paper. The splintered mass is black.

On charcoal or in the forceps it becomes brown in the interior flame, and tinges the point of the flame green. It does not fuse, but acquires a vitreous appearance on the surface, where the heat is most intense.

It is readily dissolved by borax to a transparent glass, which exhibits the color of iron while it remains hot, but after cooling it is faint copper-green in the exterior flame, and cloudy-red in the interior flame, especially if tin has been added.

It is readily and entirely dissolved by salt of phosphorus into a transparent glass, which gives the same play of colors as the borax glass.

With soda it first intumesces, and then gradually dissolves to a semi-transparent glass, which is colored by iron. With more soda it becomes infusible, and if still more be added a large quantity of copper is obtained by reduction.

\* The blue mineral from Vorau differs somewhat from this in its behavior. It intumesces considerably more, and finally crumbles to powder. It shows no signs of fusion, nor does it give a blue color with the solution of cobalt till it has undergone fusion, when it has a blue color inclining to red.

† I used for this examination a blue, reniform and a green turquoise; the latter was given me by M. Strangways, as a specimen of genuine calaité; it agreed perfectly with the description of that mineral. It was a thin layer, enveloped in a grey, clayey mass. As this specimen gave before the blowpipe traces of phosphoric acid, I analyzed it in the moist way, and found in it phosphate of alumina, phosphate of lime, silica, peroxide of iron and oxide of copper. It follows, therefore, that John's assertion, that calaité is a hydrate of alumina, is incorrect.

*Basic phosphate of alumina and lithia*, mixed with fluorides of the same bases, *Amblygonite*, from Chursdorf in Saxony.

Alone in the matrass it yields a little water, which, if the heat be intense, is acid and attacks the glass. On charcoal it fuses very readily to a transparent glass, which becomes opaque when it congeals. According to PLATTNER the presence of lithia in this mineral can be detected by the color of the flame.

It is readily dissolved by borax in any proportion to a transparent, colorless glass.

It is instantly dissolved into a transparent glass, without leaving a residuum, by salt of phosphorus.

With a little soda it fuses; with more, it intumesces and becomes infusible.

*Phosphate of lithia with lime, magnesia, protoxide of iron and protoxide of manganese. Tetraphyline*, (Perowskin) from Keiti-Tammela.

It gives water in the matrass, without undergoing any change.

In the forceps it fuses with the greatest facility to a black glass, which is attracted by the magnet.

With borax and salt of phosphorus it combines with effervescence; the resulting glass is colored by iron.

With soda on charcoal it forms a black slag; the soda is absorbed.

With soda on platina it tinges the point of the flame with the usual lilac color of lithia. The platina acquires a yellow stain, which cannot be removed by washing with water. The soda becomes intensely green.

With boracic acid and iron it gives a liquid regulus.

*Hetepozite*, from the dept. de la haute Vienne, France, behaves in all respects like the preceding.

*Three-fourths phosphate of the oxide of uranium and lime*,

$\text{Ca} \ddot{\text{P}} + 2 \ddot{\text{U}} \ddot{\text{P}} + 8 \text{H}$ . A small portion of Ca is replaced by Ba, *Uranite*, from Autun.

Alone in the matrass it yields water, and becomes straw-yellow and opaque. On charcoal it fuses, with considerable effervescence, to a black button, which has a crystalline surface.

It is readily dissolved by borax and salt of phosphorus to a transparent glass, which is dark yellow in the oxidating flame, and acquires a fine green color in the reducing flame.

It is not dissolved by soda, but forms a yellow, infusible slag.

*Three-fourths phosphate of the oxides of uranium and copper*,  $\text{Cu} \ddot{\text{P}} + 2 \ddot{\text{U}} \ddot{\text{P}} + 8 \text{H}$ , *Chalcolite*, from Cornwall, behaves

like the preceding, but gives with salt of phosphorus and tin the reaction of the protoxide of copper, and a button of copper by reduction with soda. This is sometimes white from the presence of arsenic, which can also be recognized by its smell during the operation.

#### SILICATES WITH PHOSPHATES.

*Sordawalite*, probably a mixture of  $\text{Mg}^3 \ddot{\text{P}} + 2 \ddot{\text{H}}$ , with a mineral, whose composition may be represented by

$\text{Mg}^3 \ddot{\text{Si}}^2 + \ddot{\text{Al}} \ddot{\text{Si}}^2$   
 $2 (\text{Fe}^3 \ddot{\text{Si}}^2 + \ddot{\text{Al}} \ddot{\text{Si}}^2) \quad (M S^2 + 2 f S^2 + 3 A S^2)$ , from Sordawala in Finland.

Alone in the matrass it yields a large quantity of water, which has not an acid reaction. On charcoal it fuses, without intumescence, to a black bead, which in the reducing flame acquires a grey, metallic lustre.

It is readily dissolved by borax, and gives a glass colored green by iron.

It is decomposed by salt of phosphorus, and leaves a siliceous skeleton.

With a little soda it can be fused to a black bead; with more it swells up and gives a rough slag. On platina foil it does not indicate the presence of manganese.

With boracic acid and iron I could not obtain a phosphuret of iron.

#### SULPHURIC ACID AND THE SULPHATES.\*

*Sulphate of soda*,  $\text{Na} \ddot{\text{S}} + 10 \ddot{\text{H}}$ , *Glauber's salt*.

Alone in the matrass it fuses in its water of crystallization, which can be distilled off. The dry salt fuses on charcoal, and is absorbed and converted into hepar.

If fused with soda it is absorbed by the charcoal, by which it is distinguished from salts with earthy bases.

*Sulphate of lime and soda*,  $\text{Na} \ddot{\text{S}} + \text{Ca} \ddot{\text{S}}$ , *Glauberite*, from Villarubia in Spain.

Alone in the matrass it decrepitates with violence and gives a very little water; at a low red heat it fuses to a transparent glass, from which nothing is volatilized. On charcoal the first

\* For the general test of the presence of sulphuric acid, see page 81.

action of the heat whitens it; it then fuses to a transparent bead, which becomes opaque on cooling. In the reducing flame it congeals and becomes hepatic. The sulphuret of sodium is absorbed, and the lime remains on the surface as a white globule.

It is dissolved by borax with strong effervescence; the mass is absorbed by the charcoal.

It is dissolved by salt of phosphorus with effervescence, and gives a milk-white glass.

With fluor spar it fuses like gypsum.

It is decomposed by soda; the hepatic mass is absorbed by the charcoal, and lime remains on the surface.

*Sulphate of baryta, Ba  $\ddot{S}$ , Heavy spar.*

The crystallized specimens decrepitate very violently; it fuses with great difficulty, or only becomes rounded on the edges, so that it can be distinguished from sulphate of strontian by its very slight degree of fusibility. In the interior flame it is reduced to sulphuret of barium, which, when moistened, smells slightly hepatic, and tastes strongly hepatic. It behaves, in general, like sulphate of strontian, with this difference, that when tested with hydrochloric acid and alcohol, it does not tinge the flame red.

With fluor spar it fuses like gypsum.

*Sulphate of strontian, Sr  $\ddot{S}$ , Celestine.*

Crystallized varieties decrepitate. On charcoal it fuses in the exterior flame to a milk-white bead, which, when treated in the interior flame, spreads out on the surface of the coal, and decomposes, becomes infusible, leaving a hepatic mass, which on cooling smells slightly of rotten eggs if gently breathed upon, and has a pungent and hepatic taste. On platina foil, when in this state, it is mostly dissolved by hydrochloric acid; if this solution be evaporated to dryness, the salt scraped off and placed upon a narrow, wedge-shaped strip of paper, and then moistened with alcohol and set on fire, the flame is tinged red as it comes in contact with the salt. This reaction is so distinct, that it may even be observed with heavy spar containing strontian.

It is dissolved by borax to a transparent glass, which becomes yellow or brown on cooling; if a larger quantity of the assay be employed, it becomes opaque.

It behaves with salt of phosphorus like strontian.

With soda it intumesces, is decomposed, becomes absorbed by the charcoal, and gives a strongly hepatic mass. With soda and silica it gives the usual glass colored by hepar.

With fluor spar it fuses to a transparent glass, which becomes enamel-white on cooling.

*Sulphate of lime, Gypsum.*

a. *Anhydrous gypsum,  $\text{Ca } \ddot{\text{S}}$ , Anhydrite.*

Alone in the matrass it yields no water, or only a trace.

In the forceps it fuses with difficulty in the oxidating flame to a white enamel.

On charcoal it is decomposed by a strong reducing flame, and then has an alkaline reaction on test paper, and a hepatic smell when moistened.

It dissolves with borax with effervescence, and gives a transparent glass, which becomes yellow or dark yellow on cooling. If more gypsum be added, the bead becomes brown and opaque on cooling.

With the remaining fluxes it behaves like pure lime.

With fluor spar it fuses readily to a transparent bead, which becomes enamel-white on cooling, and, if the blowing be long continued, it swells up and becomes infusible.

The following points serve to distinguish gypsum from sulphate of baryta and sulphate of strontian: *a*, the softness of gypsum; *b*, its greater degree of fusibility than that of sulphate of baryta; and *c*, that when treated on charcoal, and saturated with hydrochloric acid, it does not impart a decided red color to the flame.

b. *Hydrous gypsum,  $\text{Ca } \ddot{\text{S}} + 2 \dot{\text{H}}$ .*

Alone in the matrass it yields water, and becomes milk-white; it then behaves like the preceding.

*Sulphate of magnesia,  $\text{Mg } \ddot{\text{S}} + 7 \dot{\text{H}}$ , Epsom salt, from Calatayud in Spain.*

Alone in the matrass it yields a large quantity of water, which has not an alkaline reaction. The salt fuses, and then undergoes no farther change at the temperature at which glass melts. A drop of water heats and consolidates it. If the salt, deprived of its water, be heated on charcoal or in the forceps it fuses again. On charcoal, at a certain temperature, it suddenly emits a brilliant light, which lasts as long as the blowing is continued. The mass then becomes infusible, being deprived of its sulphuric acid. If placed on moist Brazil-wood paper, or reddened litmus paper, it colors both blue.

With borax and salt of phosphorus it behaves like magnesia.

With soda it intumesces, but does not fuse; the mass when moistened has a hepatic odor.

With the solution of cobalt it gives a beautiful, but faint, rose-red color.

*Sulphate of potash, lime, and magnesia*,  $\dot{\text{K}}\ddot{\text{S}} + \dot{\text{Mg}}\ddot{\text{S}} + 2\dot{\text{Ca}}\ddot{\text{S}} + 2\dot{\text{H}}$ , *Polyhalite*, from Ischl in Austria.

Alone in the matrass it yields water, and its color becomes paler; on charcoal it fuses to an opaque, reddish bead, which, when treated in the inner flame, congeals, becomes white, and looks like a hollow crust; it then has a saline and slightly hepatic taste.

It is readily dissolved by borax with strong effervescence, and gives, after being heated for some time, a transparent glass, which becomes clear deep red on cooling. If a large quantity of the assay be added, the glass becomes opaque on cooling.

It is dissolved by salt of phosphorus to a colorless, transparent glass. A large quantity of the assay can be added before the glass becomes opaque.

It is decomposed by soda and gives an earthy mass, which becomes yellow in the reducing flame by the admixture of hepar.

With fluor spar it fuses to an opaque bead.

*Sulphate of zinc*,  $\dot{\text{Zn}}\ddot{\text{S}} + 7\dot{\text{H}}$ , *White vitriol*, from Fahlun.

Alone in the matrass it yields water. Mixed with charcoal powder and heated, it gives a large quantity of sulphurous acid, and imparts to a glass of soda and silica, if fused with it, the color of hepar.

With the fluxes it behaves like oxide of zinc, but at the same time exhibits traces of iron.

*Sulphates of iron.*

a. *Sulphate of the protoxide of iron*,  $\ddot{\text{Fe}}\ddot{\text{S}} + 6\dot{\text{H}}$ , *Green vitriol*, *Copperas*.

b. *Red vitriol*,  $\ddot{\text{Fe}}^3\ddot{\text{S}}^3 + 3\ddot{\text{F}}\ddot{\text{S}}^2 + 36\dot{\text{H}}$ , mixed with  $\dot{\text{Mg}}\ddot{\text{S}}$ , from Insjö Sänkning, in the Fahlun mines.

c. *Vitriol ochre*,  $\ddot{\text{Fe}}^3\ddot{\text{S}} + 6\dot{\text{H}}$ .

d. *Sulphate of the peroxide of iron*,  $\ddot{\text{Fe}}\ddot{\text{S}}^3 + 9\dot{\text{H}}$ , *Coquimbite*, from Copiapo in Chili.

e. *Lamellar basic sulphate of the peroxide of iron*,  $\ddot{\text{Fe}}^3\ddot{\text{S}}^3 + 18\dot{\text{H}}$ , *Yellow copperas*, from Copiapo.

f. *Radiated basic sulphate of the peroxide of iron*,  $\ddot{\text{Fe}}^3\ddot{\text{S}}^3 + 10\dot{\text{H}}$ , from Copiapo.

These varieties have all the common property of yielding

water when heated in the matrass, and disengaging sulphurous acid when ignited, which latter can be recognized by its smell and its reaction on moistened Brazil-wood paper. The ignited substance behaves with the fluxes like pure oxide of iron. If the oxide of iron be treated with soda before all the sulphuric acid has been driven off, yellow metallic grains of magnetic iron pyrites are obtained by reduction. If the oxide of iron contains so small an amount of sulphuric acid, that its presence cannot be recognized by driving it off in the form of sulphurous acid in the usual way, it can be detected by treating the oxide of iron with soda on platina foil, and fusing the melted mass which runs from the assay with glass; if the assay contains sulphuric acid, a hepatic color is obtained.

*Basic sulphate and arseniate of the peroxide of iron. Iron sinter, (KLAPROTH'S Eisenpecherz,) from Freiberg.*

Alone in the matrass it yields a large quantity of water. At a low red heat it disengages sulphurous acid, which can be recognized by its smell, and by its property of blackening Brazil-wood paper. It does not yield a sublimate. On charcoal it shrinks together, emits white, dense fumes, and smells strongly and for a long time of arsenic. In other respects it behaves like the preceding.

If it be dissolved in salt of phosphorus, and the glass be then heated in the reducing flame till all the arsenic has been driven off, the bead becomes colored red by the protoxide of copper by the addition of tin. If the tin be added before all the arsenic has been volatilized, the bead becomes black while cooling, and the reaction of copper cannot be obtained by heating it again.

*Sulphate of cobalt*  $\text{Mg} \ddot{\text{S}} + 3 \text{Co} \ddot{\text{S}} + 28 \text{H}$ , *Cobalt vitriol, from Biber.*

In the matrass it first yields water, and afterwards, if strongly ignited, sulphurous acid, especially if a little charcoal powder be added.

With the fluxes it behaves like the oxide of cobalt.

*Sulphate of copper, neutral and basic,  $\text{Cu} \ddot{\text{S}} + 5 \text{H}$ , and  $\text{Cu}^3 \ddot{\text{S}}$ , Blue vitriol.*

It loses its color and yields water when ignited. The neutral salt becomes white, the basic black; sulphuric acid is detected in both, by pulverizing the roasted assay and mixing it with charcoal powder, and then heating it in a tube closed at one end; in this way sulphurous acid is formed in large quantity, which can be recognized by its peculiar smell, as well as by its action on a piece of Brazil-wood paper inserted into the



tube. The reaction is quite distinct, even when a piece of the basic sulphate of copper no larger than a pin-head is employed.

*Sulphate of lead*,  $\text{Pb } \ddot{\text{S}}$ , *Lead vitriol*, *Anglesite*, from Anglesea.

It decrepitates and fuses on charcoal in the exterior flame to a transparent bead, which becomes milk-white as it congeals. In the reducing flame it is reduced with effervescence to a button of lead.

With borax, salt of phosphorus, and soda it behaves like the oxide of lead.

With a glass of soda and silica it gives, on cooling, a hepatic color.

*Sulphate and carbonate of lead*, from Leadhills.

The specimen was kindly furnished me by Count BOURNON, from the private collection of the king of France. It is described under the name of "Plomb carbonaté rhomboidal" in BOURNON's Catalogue de la collection minéralogique particulière du Roi, Paris, 1817, page 343, 344.

Alone on charcoal it first intumesces a little, and becomes yellow; but on cooling it becomes white again. It is reduced to metallic lead either with or without the addition of soda.

With a glass of silica and soda it gives a hepatic color, exactly like sulphate of lead.\*

*Sulphate of alumina and potash*,  $\text{K } \ddot{\text{S}} + \ddot{\text{Al}} \ddot{\text{S}}^3 + 24 \text{ H}$ , *Alum*.

On charcoal it fuses, puffs up, and yields water. The dry mass gives sulphurous acid when heated to ignition, but no sublimate. The residuum behaves with the fluxes like alumina.

*Basic sulphate of alumina and potash*, *Alum stone*, from Tolfa, Mont d'Or, Siberia, and other localities.

Alone in the matrass it first yields water, and afterwards, at a higher temperature, a sublimate, which is soluble in water. This is sulphate of ammonia. The crystallized varieties decrepitate and crack with the greatest violence, crumbling to a fine powder, like diaspor.

On charcoal in a strong heat it shrivels up, but does not fuse.

It is dissolved by borax to a transparent, colorless glass.

Salt of phosphorus dissolves it tolerably readily, leaving a semi-transparent, siliceous skeleton. The glass does not become opalescent on cooling.

It does not fuse with soda.

It acquires a fine blue color with the solution of cobalt.

\* This mineral dissolves in nitric acid with effervescence, and leaves a white powder, which is sulphate of lead.

*Sulphate of alumina and ammonia*,  $\text{N H}^{\cdot}\ddot{\text{S}} + \ddot{\text{Al}}\ddot{\text{S}}^3 + 24 \text{ H}$ ,  
*Ammonia alum*, from Tschermig in Bohemia.

Alone in the matrass it yields water, and puffs up; afterwards sulphate of ammonia sublimes, which is mostly dissolved by the water, while sulphurous acid is disengaged. The substance which remains after ignition behaves like pure alumina.

Mixed to a paste with soda and gently heated on platina foil, it emits a perceptible ammoniacal odor.

*Neutral sulphate of alumina*, from Copiapo,  $\ddot{\text{Al}}\ddot{\text{S}}^3 + 18 \text{ H}$ .

In the matrass it yields water, and puffs up like alum.

With the fluxes it behaves like alumina. If the strongly ignited swollen mass be intimately mixed with charcoal and strongly heated in the reducing flame, it gives on silver foil the reaction of hepar.

With the solution of cobalt a blue color is obtained, which is rendered dingy by oxide of iron.

*One-third sulphate of alumina*,  $\ddot{\text{Al}}\ddot{\text{S}} + 9 \text{ H}$ , *Aluminite*, *Halite*.

Alone in the matrass it yields a very large quantity of water, and afterwards at a low red heat, sulphurous acid, which can be recognized by its smell and by its action on Brazil-wood paper.

On charcoal and with the fluxes it behaves like alumina. The aluminite from Newhaven gives a few flocks of silica, when dissolved in salt of phosphorus.

With the solution of cobalt it gives a fine blue.

*Basic sulphate of the oxide of uranium*, from Joachimsthal.

Alone in the matrass it yields water and becomes brown.

With the fluxes it behaves like oxide of uranium.

It is decomposed by soda and leaves a yellowish-brown slag on the charcoal; the soda moistened with water blackens silver.

A greenish variety gives a button of copper by reduction with soda, and traces of the protoxide of copper, if its solution in the fluxes be treated with tin.

#### SILICATES OF SODA, LIME AND ALUMINA, COMBINED WITH SULPHATES.

*Lapis lazuli*, a fragment of a very pure specimen, having a natural cleavage, furnished me by M. CORDIER.

Alone in the matrass it yields water, without changing its appearance or losing its transparency. On charcoal it fuses slowly to a white glass, which is shaded with blue when the

bead first begins to liquefy; this color, however, entirely disappears on farther heating. The mineral becomes spotted with blue, and close by the fused portion, dark green. The lapis lazuli which is destitute of a foliated structure fuses more readily, with slight intumescence.

Borax dissolves it with constant effervescence to a transparent, colorless glass. The fragment, as it lies in the bead before dissolving, gives out a stronger light than the glass itself.

It is completely dissolved by salt of phosphorus, with constant effervescence and with the same phenomena of light, into into a colorless glass, without leaving a siliceous skeleton; the glass becomes clouded on cooling.

It is imperfectly dissolved by soda into an opaque, greyish-green glass, which becomes red on cooling, indicating the formation of hepar. A larger addition of soda has no other effect than to render the glass more soluble in water; it then gives a stain of sulphur on silver foil.

*Hauyne*, from Italy, and *Nosian*, from the lake of Laach.

Alone in the matrass they yield no water. On charcoal they lose their color and fuse to a blebby glass.

With borax they dissolve with effervescence to a transparent glass, which becomes yellow on cooling, as if gypsum were present in the mineral. The saturated glass becomes opaque on cooling.

They are dissolved by salt of phosphorus with effervescence, and leave a siliceous skeleton. The glass is opalescent.

They are slowly attacked by soda, and give only on the extreme edges a vitreous slag, which on cooling becomes tinged with the usual red color of hepar.

## COMBINATIONS OF HALOGEN SUBSTANCES.

### CHLORIDES.\*

*Chloride of sodium*,  $\text{Na Cl}$ , *Common salt*.

Alone in the matrass it decrepitates and yields water. On charcoal it fuses and is absorbed by the charcoal, at the same time emitting fumes. On platina foil it fuses to a transparent mass, which becomes opaque on cooling.

It fuses on platina foil without becoming clouded.

\* For the general test for the detection of chlorine in the chlorides, see page 82.

*Chloride of ammonium*,  $\text{N H}^4 \text{Cl}$ , *Sal ammoniac*.

In the matrass it sublimes, without previously fusing, and without leaving any residuum.

Mixed to a paste with soda and water and heated on platina foil, it smells strongly of ammonia.

*Chloride of lead*,  $\text{Pb Cl}$ , *Cotunnite*, from Vesuvius.

In the matrass it does not yield water. On charcoal it fuses readily, spreads upon the surface, and gives off fumes.

With soda it gives a quantity of globules of lead.

*Basic chloride of lead*,  $\text{Pb Cl} + 2 \text{Pb}$ , from Mendiff.

It decrepitates slightly, fuses readily, and becomes after cooling yellower than it was at first. When ignited it is easily reduced to metallic lead, while acid vapors are disengaged.

*Basic chloride of copper*,  $\text{Cu Cl} + 3 \text{Cu} + 4 \text{H}$ , *Muriate of copper*, *Atacamite*, in the form of sand, and compact, from Chili.

Alone it tinges the flame intensely blue with greenish edges, and a red coating is deposited upon the charcoal, which colors the flame blue, when directed upon the surface of the support. It fuses, is reduced, and gives a button of copper surrounded by a slag. The pulverulent mineral gives more slag than the compact variety. The glass exhibits, in addition to the reaction of copper, that of iron, which is best observed in the reduced glass, before the color of the copper becomes evident by cooling.

With the fluxes it behaves like oxide of copper.

*Chloride of silver*,  $\text{Ag Cl}$ , *Horn silver*.

Alone on charcoal it fuses to a bead, which varies in color, according to the purity of the assay, from pearl-grey to brown, or is even black and slaggy. In the reducing flame it is gradually converted into metallic silver, and finally leaves a button of pure silver.

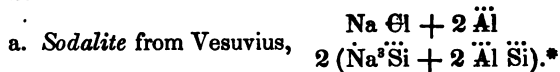
*Chloride of mercury*,  $\text{Hg Cl}$ , *Horn quicksilver*, (Hornerz,) from Almaden.

On charcoal it volatilizes entirely, with the exception of portions of the gangue which it may contain.

In the matrass it gives a white sublimate.

With soda in the matrass it gives an abundance of globules of mercury.

## SILICATES WITH CHLORIDES.

*Sodalite.*

Alone in the matrass it gives no trace of water. On charcoal it undergoes no change, but if the heat be very intense it becomes rounded on the edges, without puffing up or bubbling, and retains its transparency.

Borax dissolves it in trifling quantity, and with the greatest difficulty, to a transparent, colorless glass.

It does not intumescence with salt of phosphorus; it is slowly dissolved, without being decomposed. The glass is opalescent on cooling.

With a small quantity of soda it forms a transparent glass, which surrounds the undissolved portion. A larger quantity of soda decomposes the mineral, which then swells up and becomes infusible. If still more soda be added it fuses to an opaque, colorless glass.

With the solution of cobalt it becomes blue on the fused edges.

*b. Sodalite, from Greenland.*

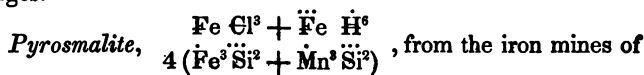
Alone in the matrass it yields water; the mineral, however, undergoes no change in appearance, and does not lose its transparency. On charcoal it fuses with strong intumescence and bubbling, and gives an uneven, but colorless glass.

With borax it behaves like the preceding.

It is very slowly decomposed by salt of phosphorus; after blowing for some time it can be observed, that the mineral has acquired a siliceous appearance on its edges. The glass is opalescent on cooling.

It gives a glass with soda, with far greater difficulty than the variety from Vesuvius. The bead is opaque.

With the solution of cobalt it becomes blue on the fused edges.



Nordmark.

Alone in the matrass it first yields water, and afterwards, at a higher temperature, a yellow substance, which dissolves into

\* This formula is exactly the result of ARFVEDSON'S analysis.

yellow drops with the portion of water last given off. These drops redden litmus paper, and have an astringent taste. They are chloride of iron. On charcoal it gives, when gently heated, a faint acid smell; it fuses readily to a smooth, brilliant, iron-grey bead.

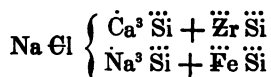
It dissolves with borax with the usual tinge of iron.

It is less readily taken up by the salt of phosphorus; it remains for some time as a dark substance in the glass. It is finally dissolved, and acquires the characteristic color of iron, leaving a minutely divided siliceous skeleton. With saltpetre the glass exhibits strong traces of manganese.

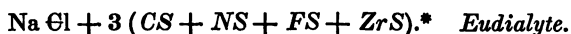
It has the characteristic reaction of manganese when treated with soda on platina foil. On charcoal it gives a black glass, which when treated with more soda is absorbed by the charcoal.

If a small fragment of pyrosmalite be placed in contact with a solution of the oxide of copper in salt of phosphorus, and both be heated at the same time, a light blue ring is formed around the bead, as is the case with hydrochloric acid; this lasts, however, but an instant.

*Two-thirds silicate of soda, lime, protoxides of iron and manganese and zirconia with chloride of sodium*, which according to STROMEYER'S analysis may give the following formula:



or the following empirical formula:



In the matrass it yields a small quantity of moisture. It fuses readily on charcoal to a greenish-grey glass.

It is readily dissolved by borax, and gives a glass faintly tinged by iron, which cannot be rendered opaque by flaming.

It is readily decomposed by salt of phosphorus; the siliceous skeleton swells up so that the bead generally loses its spherical shape. This circumstance serves to distinguish it from the garnet, which it otherwise strongly resembles.

It gives with soda a glass, which is very difficultly liquefiable; with more soda it is absorbed by the charcoal. On platina foil it gives the reaction of manganese.

\* In this formula, the oxygen of the oxide of manganese is reckoned with that of the oxide of iron.

## PHOSPHATES WITH CHLORIDES.

*Phosphate of lime with chloride of calcium*, the latter often replaced by fluoride of calcium,  $\text{Ca Cl} + 3 \text{Ca}^3 \ddot{\text{P}}$ , *Apatite*.

a. *Moroxite*, from Arendal and Pargas.

Alone it remains unchanged, but in thin laminæ, at a very high temperature, it can be fused on the edges to a colorless, translucent glass; it is, however, one of the most difficultly fusible minerals.

It is slowly dissolved by borax to a transparent glass, which can be rendered milk-white by flaming, and which with a larger quantity of the assay becomes opaque on cooling.

It is dissolved in large quantity by the salt of phosphorus to a transparent glass, which, when nearly saturated, becomes opaque on cooling, and acquires a crystalline appearance, less distinct, however, than that of phosphate of lead. If fully saturated it hardens to a milk-white bead, without crystalline facets.

With soda it swells up with effervescence, the soda is absorbed by the charcoal, and leaves a white mass.

It is very slowly dissolved by boracic acid, but gives with metallic iron a regulus of phosphuret of iron.

b. *Radiated phosphate of lime*, *Phosphorite*, from Estremadura; it gives in the matrass a little water, and fuses, rather more readily than the preceding, to a white enamel. In general, its behavior is the same as that of the preceding.

c. *Phosphate of lime*, from mammoth's teeth, (dug up near Kannstadt.)

In the matrass it shrivels up and gives a large quantity of water.

On charcoal it blackens on the edges, where the flame acts on it; it does not fuse, but becomes semi-transparent and rounded on the edges, where the heat is most intense. It behaves in other respects like the preceding.

*Phosphate of the oxide of lead with chloride of lead*,  $\text{Pb Cl} + 3 \text{Pb}^3 \ddot{\text{P}}$ , *Pyromorphite*, (Grünbleierz.)

Alone on charcoal it fuses in the exterior flame, the globule crystallizes, and becomes dark colored on cooling. Treated in the interior flame, it emits fumes of lead, the flame is tinged with blue, and the globule on cooling crystallizes with large facets of a pearly-white color and lustre. At the moment of crystallizing, the bead becomes slightly red hot.

With borax, salt of phosphorus and soda it behaves like the oxide of lead.

With boracic acid and iron it gives phosphuret of iron and metallic lead, which can be separated from each other after the phosphuret of iron becomes hardened, and while the lead is still liquid. The lead does not give a button of silver when cupelled on bone ashes.

*Plumbo-resinite*,  $\text{Pb}^3 \ddot{\text{P}}$  with  $\ddot{\text{Al}} \text{H}^3$ , in variable proportions, (Bleigummi,) from Huelgoat.

Alone in the matrass it flies in pieces violently, and gives a large quantity of water; carefully heated on charcoal it becomes milk-white, swells up like a zeolite, and softens if strongly heated, but cannot be entirely fused.

It is readily dissolved by borax to a transparent glass.

The same is true with salt of phosphorus. With a large proportion of the assay the bead becomes opaque on cooling.

It is not dissolved by soda, but globules of lead make their appearance on all sides.

With boracic acid and iron it gives a fused phosphuret of iron.

With the solution of cobalt it gives a fine blue.

#### ARSENIATES WITH A CHLORIDE.

*Arseniate of the oxide of lead with chloride of lead*,  $\text{Pb Cl}$

+  $3 \text{ Pb } \ddot{\text{As}}$ , from Johann-Georgenstadt and Cornwall.

Alone on charcoal it fuses slowly, and then becomes instantly reduced to a quantity of globules of metallic lead, emitting copious fumes and the odor of arsenic. With the fluxes it behaves like the oxide of lead, with this difference, that the glass emits fumes of arsenic.

If a crystal of arseniate of lead be held in the forceps, and the extreme end of it fused in the exterior flame, the fused portion crystallizes like phosphate of lead. The fused substance, however, must not touch the platina, since in that case it flows out and destroys the metal. The fused mass flows out in the same way upon glass.

*Remark.* Arseniate of lead, containing phosphate of lead, is not perfectly reduced, but leaves the phosphate as a fused, crystallized bead. Phosphate of lead contaminated with the arseniate gives metallic lead, and smells of arsenic when fused in the reducing flame.



## CARBONATE WITH A CHLORIDE.

*Carbonate of the oxide of lead with chloride of lead*,  $\text{Pb Cl} + \text{Pb C}$ , from Matlock, behaves like basic chloride of lead.

## FLUORIDES.\*

*Fluoride of calcium*,  $\text{Ca F}$ , *Fluor spar*.

Alone in the matrass it often phosphoresces when gently heated, emitting in the dark a greenish light. At a high temperature it decrepitates strongly, and gives a very little water. It can be fused on charcoal to an opaque bead.

It is dissolved by borax and salt of phosphorus with the greatest facility to a transparent glass, which at a certain degree of saturation becomes opaque.

With a certain portion of soda it dissolves and gives a transparent glass, which becomes opaque when it hardens, or if heated for a long time; with a large quantity of soda it is converted into a difficultly fusible enamel, which remains on the charcoal, while the excess of the flux is absorbed.

With gypsum, heavy spar or sulphate of strontian it fuses readily to a transparent bead, which becomes opaque on cooling. See gypsum.

*Fluoride of calcium with fluorides of yttrium and cerium*,  $\text{Ca F}$ ,  $\text{Y F}$ ,  $\text{Ce F}$ , in variable proportions, *Ytthro-cerite*.

a. *Ytthro-cerite*, from Finbo.

Alone in the matrass it yields water, which has a burnt smell. The dark colored variety loses its color and becomes white. On charcoal it does not fuse, but on the addition of gypsum it fuses to a bead, which does not become transparent at any temperature.

With borax, salt of phosphorus, and soda it behaves like fluor spar; the glass is, however, yellow in the oxidating flame as long as it remains hot; it becomes opaque sooner than the glass given by fluor spar.

b. *Ytthro-cerite*, from Broddbo.

It decrepitates slightly, does not fuse, and becomes first milk-white and then brick-red, but different portions of its surface are unequally colored. It does not fuse with gypsum, and it behaves in general like fluoride of cerium, of which it contains a large proportion intermixed.

\* For the method of detecting fluoric acid, see page 83.

*Fluoride of cerium*,  $\text{Ce F}$ , mixed with  $\text{Ce F}^3$ , from Finbo, Broddbo and Bastnäs.

a. *Neutral*, from the two first localities.

Alone in the matrass it yields water, and if raised to the melting-point of glass, the glass becomes corroded at a little distance from the assay. The water given off tinges Brazil-wood paper yellow. The assay changes from a yellowish color to white in the operation. If heated in an open tube, into which the flame is directed, the interior of the tube is attacked, and is rendered opaque by the deposition of silica. The assay becomes dark yellow.

On charcoal it does not fuse; its color becomes, however, somewhat darker.

With borax and salt of phosphorus it behaves like the oxide of cerium. It is not dissolved by soda, but it divides and swells up; the soda is absorbed by the charcoal, and leaves a grey mass on the surface.

b. *Basic*, from Finbo,  $\text{Ce F}^3 + 3 \ddot{\text{Ce}} \ddot{\text{H}}$ .

On charcoal its color is changed by the heat, and it appears almost black, at a low red heat; on cooling, however, it becomes dark brown, clear red, and finally dark yellow. These changes of color serve to distinguish it from the neutral variety, in which no such changes take place. It does not fuse. With the fluxes it behaves, in general, like the preceding, except that it is not divided by soda, but remains whole, unless strongly heated for a long time.

*Fluate of cerium*,  $\text{Ce F}^3 + \dot{\text{Ce}} + 4 \ddot{\text{H}}$ , from Bastnäs.

Alone in the matrass it gives a little moisture, without changing its appearance. On charcoal it does not fuse, but becomes opaque when gently heated. It acquires a dark color, and undergoes the same changes of color as the preceding.

Heated in the open tube by directing the flame into the tube, it gives a strong reaction of fluoric acid.

It is dissolved by borax and salt of phosphorus like the preceding.

It does not crumble in pieces with soda, neither does it intumesce or fuse.

*Remark.* This seems to be a basic salt, perhaps with less excess of base than the preceding variety.

*Fluoride of cerium with fluoride of yttrium*,  $\text{Ce F}$ ,  $\text{Y F}$ , *Fluate of yttria with fluate of cerium*, from Finbo; generally an earthy mechanical mixture of the two, which also contains silica, either in the form of a silicate, or merely intermixed.

It behaves like the neutral fluato of cerium, with this difference, that a large quantity of it must be added to the borax glass before it can be rendered opaque by flaming. The more siliciferous earthy varieties give with soda a coherent, slaggy mass, which is not changed by a further addition of soda.

*Fluoride of sodium with fluoride of aluminium,  $3 \text{ Na F} + \text{Al F}_3$ , Cryolite, from Greenland.*

Alone in the matrass it yields a little water and decrepitates, without losing its transparency. If heated in the open tube by directing the flame within the tube, it corrodes the glass strongly, and the moisture which collects in the tube reacts like fluoric acid. On charcoal it fuses to a transparent bead, which becomes opaque on cooling. If the heat be continued for some time, it spreads out on the surface, the fluato of soda is absorbed by the charcoal, and a crust of alumina remains.

It is dissolved by borax, readily and in large quantity, to a transparent glass, which becomes milk-white on cooling. It behaves in the same way with the salt of phosphorus. The bead has sometimes a slight reddish tinge from a small quantity of copper in the mineral.

With soda it fuses to a transparent glass, which spreads out on cooling, and becomes milk-white.

#### SILICATES WITH FLUORIDES.

*One-third silicate of magnesia with basic fluoride of magnesium,  $\text{Mg F} + 2 \text{ Mg}^{\text{s}} \text{ Si}$ , Chondrodite, from Pargas, Åker and from America, Brucite.*

Alone in the matrass it burns black, but yields no water; the black color is burnt off by heating it in the open air. Strongly heated in the open tube, it gives the reaction of fluoric acid.

On charcoal it cannot be fused. The variety which contains iron becomes opaque and brownish, where the heat is strongest. The varieties containing a smaller proportion of iron, for instance that from Åker, become milk-white.

Borax dissolves it slowly, but perfectly, to a transparent glass, slightly tinged by iron. If the glass is saturated with the assay, it can be rendered cloudy by flaming; it does not become milk-white, but semi-transparent and crystalline.

It is tolerably readily dissolved by the salt of phosphorus, leaving a semi-transparent siliceous skeleton; the glass is transparent and colorless, but becomes opalescent on cooling.

With a certain proportion of soda it forms a very difficultly

fusible, grey slag. With more it swells up and becomes infusible.

With the solution of cobalt it gives at a high temperature a faint red color, which, however, is not clear and beautiful. Chondrodite from Pargas gives a greyish-green color, because the presence of iron prevents the action of the oxide of cobalt on the magnesia.

*One-third silicate of alumina with basic fluoride of aluminium,  $2 \text{AlF}_3 + 5 \text{AlSi}$ , Topaz, and  $2 \text{AlF}_3 + \text{AlSi}^5$ , Pycnite.\**

Alone in the matrass it remains unchanged, and does not give the least trace of fluoric acid, but if strongly heated in the open tube according to the method proposed by SMITHSON, it gives indications of the presence of this acid. On charcoal it is infusible. The yellow topaz becomes pale rose-red when gently ignited, while the hydrated oxide of iron is converted into a simple oxide. This variety, as well as the transparent, colorless topaz, retains its transparency. If the heat be very intense, the lateral planes of the crystal become covered with numerous small bubbles, like hoar-frost; they cannot be distinctly seen without the aid of the microscope. The bubbles do not appear on the foliated cross-fracture, and they are not so easily made to appear on the opaque topaz from Finbo and Broddbo; but if the heat be sufficiently strong, they can be obtained of considerable size, although they generally burst almost immediately after they first make their appearance. To succeed in this operation, a very intense heat is required, and only a very thin splinter of the mineral must be used.

It is slowly dissolved by borax to a transparent glass. The transparent topaz becomes white and opaque before it dissolves.

It is slowly dissolved by salt of phosphorus, leaving a siliceous skeleton; the transparent bead becomes opalescent on cooling.

It is slowly dissolved by soda and gives a blebby, colorless, semi-transparent slag. With more soda it swells up and becomes infusible.

With the solution of cobalt it gives a blue color, which, however, is not clear and beautiful. TURNER states that he obtained evidence of the presence of boracic acid in many varieties of topaz, by the aid of fluor spar and bisulphate of potash.

*Remark.* To this class of combinations belong, in all probability, amphibole, carpholite, and perhaps several others in which no fluor has as yet been discovered. Fluorides enter into

\* The formulæ of the topaz and pycnite were calculated from new analyses of these minerals, furnished by Professor Forchhammer.

combination with phosphates like chlorides, and probably Wavellite, amblygonite, and Wagnerite belong to this class.

*Leucophane*,  $2 \text{ Na F} + \text{Ca}^2 \ddot{\text{Si}}^2 + \ddot{\text{G}}^2 \ddot{\text{Si}}^3$ , from Lamanskär, Norway.

Alone on charcoal it fuses readily, without foaming, to a transparent globule, of which the color inclines to violet. The glass is rendered opaque by flaming, and cannot be made transparent again without considerable difficulty.

It is dissolved by borax with the utmost facility and in large quantity. The glass is transparent, and does not become opaque when flamed.

It is readily dissolved by the salt of phosphorus. The glass becomes opalescent on cooling. With salt of phosphorus in the tube, it gives the usual evidence of the presence of fluor.

With a small amount of soda it gives a transparent glass. With more, it spreads over the surface of the charcoal.

With soda on platina foil it exhibits traces of manganese.

## SUPPLEMENT.

---

### *Honey stone, Mellite, Mellate of alumina.*

Alone in the matrass it yields water, whitens, and becomes transparent. If ignited it becomes carbonized, without emitting any perceptible burnt odor, and without coloring the water given off, or acquiring an acid or alkaline reaction. On charcoal it becomes black, ignites, and burns white if the heat is sufficient, at the same time shrivelling up strongly. It behaves like pure alumina.

### *Chiastolite, Macle, from Brittany.*

Alone it yields a little water, without changing its appearance. It burns white, but does not fuse. The pulverized mineral can be fused to a slag on the thinnest edges of the mass.

It is very slowly acted on by borax, even if pulverized.

Salt of phosphorus seems to have little or no action on it, but the bead remains clear, colorless, and transparent. If, however, the finely pulverized mineral be added gradually, the first portions are dissolved without a residuum; but it very soon ceases to be dissolved.

It is decomposed by soda and swells up, but does not fuse or become converted into a slag.

It becomes blue with the solution of cobalt, but the color is dark and dingy; the color is finer in proportion to the purity of the specimen examined.

*Remark.* The reaction of the chiastolite proves it to be a silicate of alumina, and in all probability a subsilicate. I must, however, add, that some varieties of chiastolite are principally composed of magnesia. These are easily distinguished by their softness from the variety of which the behavior is here described.

## SYSTEMATIC ARRANGEMENT

OF THE

## OXIDIZED MINERALS

ACCORDING TO THEIR BEHAVIOR BEFORE THE BLOWPIPE.

---

When the nature of a mineral is to be determined by its behavior before the blowpipe, the external characters not being sufficiently distinct for that purpose, it is important, especially for young mineralogists, that some arrangement should be contrived, by which the number of species, with which the mineral under examination is to be compared, should be diminished so as to be as small as possible. I have endeavored to form such a systematic arrangement, which, although deficient in many respects, will not be without use. I have considered, especially, three properties of minerals; namely, fusibility, intumescence, and behavior with soda. The principal divisions depend on the two former properties, the subdivisions on the latter.

1. *Infusible Minerals.*

Give with soda a bead.	Give with a small quantity of soda a bead, but form a slag with more.	Give a slag only with soda.
Quartz Agalmatolite Hisingerite Sideroschisolite Diopase Fire clay Leucite Pyrophyllite Wolkonskoite Rutile	Phenakite Picrosmine Olivine Cerite Kyanite Talc Gadolinite Lithia tourmaline	Oxides of iron Oxides of manganese Oxide of tin (is reduced) Hydrate of alumina Hydrate of magnesia Spinel Gahnite Wörthite Precious galmey Pitchblende Zircon Thorite Andalusite Staurotide Gehlenite Chlorite spar Allophane Cymophane Polymignite Aeschynite Oerstedine Titanate of iron Yttrio-tantalite Tantalite Chrome ochre Uwarowite Chromic iron Carbonates of earths and metals Basic phosphate of yttria Basic phosphate of alumina Basic phosphate of lime Sulphate of iron Sulphate of alumina Aluminite Alum stone Fluoride of cerium Yttrio-cerite Topaz



2. *Minerals which can be fused to beads.*

Fuse with soda to a bead.	Give with a small quantity of soda a bead, with more a slag.	Give a slag only with soda.
The zeolites	Okenite	Brevicite
Spodumene	Pectolite	Amphodelite
Soda-spodumene	Red silicate of manganese	Chlorite
Labradorite	Black silicate of manganese	Fahlunite
Scapolite	Idocrase	Pyrope
Sodalite (from Greenland)	Manganesian garnet	Soapstone
Elaeolite	Orthite	Red dichroite
Mica from primitive limestone	Pyrothite	Pyrargillite
Black talc	Amblygonite	Potash tourmaline (black)
Acmite	Sordawalite	Wolfram
Crocidolite	Sodalite	Pharmacolite
Lievrte	Fluor spar	Scorodite
Cronstedtite	—	Cube ore
Garnet	Give with soda a reguline metal.	Tetraphylene
Cerine		Hetepozite
Helvine		Uranite
Gadolinite (from Karsarvet)	Tungstate of lead	Phosphate of iron
Boracic acid	Molybdate of lead	Sulphate of strontian
Tincal	Vanadate of lead	Sulphate of magnesia
Boracite	Chromate of lead	Polyhalite
Hydroboracite	Vauquelinite	Hauyne
Datholite	Cobalt bloom	
Botryolite	Nickel bloom	
Axinite	Phosphate of copper	
Lapis lazuli	Sulphate of lead	
Eudialyte	Chloride of lead	
Pyrosmalite	Chloride of silver	
Cryolite		

3. *Minerals which can be fused only on their edges.*

Give with soda a liquid bead.	Give with a small quantity of soda a liquid bead, but with more a slag.	Give a slag only with soda.
Soapstone	Table spar	Stilpnosiderite
Feldspar	Diallage.	Plumbo-resinite
Albite	Hypersthene	Serpentine
Petalite	Epidote	Silicate of manganese, from Piedmont
Nepheline	Zoisite	Mica, from granite
Anorthite		Pimelite
Emerald		Pinite
Euclase		Blue dichroite
Calaité		Carpholite
Sodalite (from Vesuvius)		Sphene
		Pyrochlore
		Wolfram
		Soda tourmaline (green)
		Lazulite
		Heavy spar
		Gypsum

4. *Minerals which intumesce.*

Fuse to a bead.	Become slaggy on the edges.	Infusible.
The zeolites	Epidote	Gadolinite, some varieties
Onkosine	Zoisite	Lithia-tourmaline
Boracite	Green tourmaline	Aeschynite
Hydroboracite	Lazulite	Pyrophyllite
Datholite	Plumbo-resinite	Alum
Botryolite	Granite mica	Sulphate of alumina
Axinite	Hornblende	
Black silicate of manganese	Euclase	
Lithia-spodumene	Sphene	
Scapolite		
Elaeolite		
Idocrase		
Cerine		
Orthite		

## BEHAVIOR OF URINARY CALCULI BEFORE THE BLOWPIPE.

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It is highly important to medical men to be able to determine the nature of the urinary calculi of patients who apply to them for relief in such cases. Their composition is more readily ascertained than is generally supposed, since the blowpipe gives very simple and sufficiently accurate results, and the use of this instrument does not require a greater degree of chemical knowledge than every physician ought to possess. I will therefore describe the following varieties of calculi.

### 1. URIC ACID CALCULI.

Alone on charcoal or on platina foil they become carbonized, fume, and emit an organic smell; in the exterior flame they gradually diminish in size, and towards the end of the operation they burn with increased light. When the blast is discontinued, they still continue to glow, and at last leave a very slight trace of a white ash, which is strongly alkaline.

Since other combustible substances may easily be mistaken for uric acid, the operation must be performed in the moist way, as follows: a small quantity of the calculus, say  $\frac{1}{10}$  of a grain, must be placed on a small strip of glass or platina foil, moistened with a few drops of nitric acid, and heated over the flame of the spirit-lamp. The uric acid dissolves with effervescence, and the mass must then be carefully dried so as not to become burnt, and then heated for an instant, when the mass acquires a fine red color. If the quantity of uric acid in the assay is trifling, the latter often becomes black, without acquiring a tinge of red. The experiment must then be repeated, and when the solution in nitric acid is dry, it must be laid aside and allowed to cool perfectly; the glass must then be inverted over a little caustic ammonia, which is then to be heated; as soon as the

vapor of the ammonia reaches the dried substance, it becomes beautifully red.\* The same thing may be observed, though the color is less striking, if the dried substance be softened with diluted ammonia.

It often happens that calculi contain a mixture of uric acid with earthy phosphates. They then carbonize and consume, leaving a considerable residuum, which is not alkaline or soluble in water. Treated with nitric acid and afterwards with ammonia, they give the fine red color characteristic of uric acid. The remaining ash is either phosphate of lime, or phosphate of magnesia, or a mixture of both.

## 2. URATE OF SODA CALCULI.

This substance, which rarely occurs in urinary calculi, is often contained in the hard excrescences which form around the joints of gouty patients.

Alone on charcoal they blacken, emit a burnt organic odor, and leave a grey, strongly alkaline substance, which can be fused to a glass with silica. If the calculus contains earthy salts, as is usually the case, the glass becomes white, or greyish and opaque.

## 3. URATE OF AMMONIA CALCULI.

They behave before the blowpipe like the uric acid calculi. Treated with a drop of caustic potash, they give, when slightly warmed, a strong smell of ammonia. Care must be taken not to confound this with the slight ammoniacal odor which almost all organic substances develop when treated with potash. These calculi often contain a quantity of urate of soda.

## 4. PHOSPHATE OF LIME CALCULI.

Alone on charcoal they blacken, emit the odor of burning organic matter, and finally burn white. They do not fuse. Their behavior resembles in general that of phosphate of lime.

They are proved not to consist of silica, by swelling up with soda and not fusing to a glass, as well as by giving a regulus of phosphuret of iron, when dissolved in boric acid and fused with iron.

\* This method of detecting ammonia was discovered by Professor Jacobson of Copenhagen, who first detected the existence of uric acid in the excretions of animals of the lowest class.

### 5. AMMONIACAL PHOSPHATE OF MAGNESIA CALCULI.

Heated alone on platina foil they smell strongly of salts of hartshorn, blacken, swell up, and burn greyish-white if the heat be increased. They fuse readily to a greyish-white, enamel-like bead.

They give a transparent glass with borax and salt of phosphorus, which with a large quantity of the assay becomes milk-white on cooling.

With soda they fuse to a white, swollen slag, which becomes infusible on the addition of more soda.

With boracic acid and iron they give readily a regulus of phosphuret of iron.

With nitrate of cobalt they give a dark red glass.

### 6. CALCULI COMPOSED OF THE PHOSPHATES OF LIME AND MAGNESIA. (*Calculi fusibiles*.)

These are recognized by the slight ammonical odor which they emit, which arises principally from the destruction of organic matter in the calculus. They fuse far more readily than any others to an enamel-white bead, which does not become red with the oxide of cobalt, but brownish-black.

### 7. CALCULI COMPOSED OF OXALATE OF LIME. (*Calculi moriformes*.)

Alone they smell of urine when first heated. The more strongly crystalline varieties become duller and lighter colored. After being slightly heated, the residuum effervesces with a few drops of nitric acid, and after being strongly heated on charcoal caustic lime remains; this has an alkaline reaction on reddened litmus paper, and generally crumbles to powder when moistened. This is not the case, however, if the calculus contains at the same time phosphate of lime.

### 8. CALCULI CONTAINING SILICA.

They leave after ignition a greyish, infusible, and sometimes slaggy ash, which, when mixed with soda, slowly dissolves to a more or less transparent glass.

### 9. CYSTIC OXIDE CALCULI.

These behave before the blowpipe very much like calculi composed of uric acid; they do not fuse, but take fire readily

## 230 BEHAVIOR OF URINARY CALCULI BEFORE THE BLOWPIPE.

and burn with a bluish-green flame, emitting a strongly acid smell of a peculiar character, somewhat resembling that of cyanogen. They leave an ash which is not alkaline, and which fuses in a strong heat to a greyish-white mass.

They are distinguished from uric acid calculi by the smell which they emit when burning, and by not giving a red color with nitric acid.

*Remark.* I have not had an opportunity of examining the calculi composed of a peculiar substance, discovered by MARCET, which he calls xanthic oxide.

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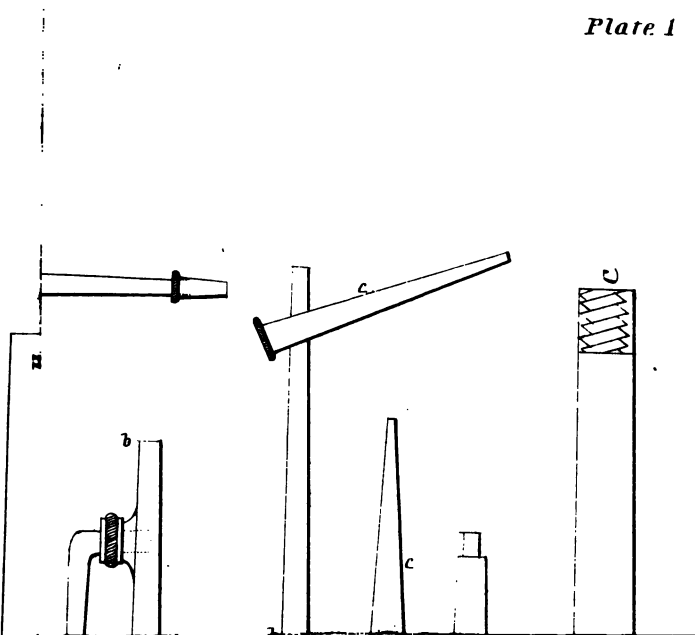
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Fig. 9







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